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A TREATISE ON THE EYE,

The MANNER and PHÆNOMENA of VISION.

IN TWO VOLUMES.

By WILLIAM PORTERFIELD, M.D.
Fellow of the Royal College of Phyſicians
at *Edinburgh.*

MANCHESTER MEDICAL SOCIETY

VOL. I.

> —*Whence is it that Nature doeth nothing in vain, and whence ariſes all that Order and Beauty we ſee in the World?*——*How came the Bodies of Animals to be contrived with ſo much Art, and for what Ends were their ſeveral Parts? Was the Eye contrived without ſkill in Optics, and the Ear without knowledge of Sounds?* &c. NEWTON's Opticks, Query 28.

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TO

Sir ALEXANDER DICK

of PRESTONFIELD, Baronet,

PRESIDENT,

AND TO

The COUNCIL and FELLOWS

OF THE

ROYAL COLLEGE of PHYSICIANS

AT

EDINBURGH:

This TREATISE on the EYE, *&c.*

is moſt humbly Dedicated,

By their moſt Obedient Servant,

WILLIAM PORTERFIELD.

MANCHESTER MEDICAL SOCIETY

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A TREATISE ON THE EYE, the Manner and *Phænomena* of VISION.

BOOK I.

Of the Parts ſubſervient to the Eye.

CHAP. I.

Of the Supercilia *or Eye-brows.*

SECT. 1. OF all the Parts of the Body, there is none whoſe Structure and Mechaniſm diſcovers more Art and Deſign, than this little Organ the Eye; all its Parts are ſo excellently well contrived, ſo elegantly formed, and nicely adjuſted, that none can deny it to be an Organ as magnificent and curious as the Senſe is uſeful and entertaining.

By means of this Organ, we diſcover the Magnitude, Figure, Diſtance, Situation, Motion, Colour and Beauty of Bodies: Without it, as all the Animal World would be in perpetual Darkneſs, ſo it would labour under perpetual Inconveniencies, be expoſed to perpetual Harms, and ſuffer perpetual Wants and Diſtreſſes: But now, by this admirable Senſe, we are enabled to ſee and chuſe wholeſome, yea delicate Food, provide ourſelves uſeful, yea gaudy Cloathing, and commodious Places for Habitation and Retreat: We can diſpatch our Affairs with Alacrity and Pleaſure, go here and there as our Occaſions call us, and, by looking about us, can diſcern and ſhun the Precipices and Dangers which would deſtroy us; we can now, if need be, ranſack the whole Globe, penetrate into the Bowels of the Earth, deſcend into the Bottom of the Deep, travel to the fartheſt Regions of the World, to acquire Wealth, to increaſe our Knowledge, or even only to pleaſe our Fancy, and ſatisfy our Curioſity. And thoſe glorious Objects which fill the Heavens and the Earth, thoſe admirable Works of Nature which every where ſurround us, and which would be as nothing to us without being ſeen, do, by means of this noble Organ, preſent their Glories to our View, and fill us with Admiration and Delight. In a word, without the Benefit of Light, the animated Part of this Syſtem would be but ſo many

Puppets toſt up and down by Chance and Fortune, without Houſe or Habitation, and deprived of all the Pleaſures and Conveniencies of Life. What a miſerable State would it be, to be confined to perpetual Darkneſs, and never to behold the chearful Light? But I need not expatiate on the Uſefulneſs and Praiſes of this Senſe, which we receive the Benefit of every moment, and the Want, or any Defect of which we lament among our greateſt Misfortunes. I ſhall therefore proceed to examine the beautiful Structure of the Eye, from which we receive ſo many Advantages.

§ 2. For our clearer Proceeding in this Matter, I ſhall divide this Organ, after the common Manner of Anatomiſts, into two Parts, *viz.* the *Internal*, which is the Globe or Body of the Eye itſelf, formed by the *Tunica cornea* and *Sclerotica*, and the Parts contained in them; and the *External*, which are thoſe Parts about the Globe ſubſervient to it, ſuch as the *Supercilia* or Eye-brows, the *Cilia* or Eye-laſhes, the *Palpebræ* or Eye-lids, the *Glandula Lachrymalis* or *Innominata*, the *Caruncula* and *Puncta Lachrymalia*, &c. All which we ſhall deſcribe in Order, beginning with the External Parts. And firſt of the *Supercilia* or Eye-brows.

§ 3. The Eye-brows, as every Body knows, are nothing elſe, but ſome Hairs placed above the Eye, which ſerve to defend it from Light when too ſtrong, and eſpecially from Duſt, Mots, and ſuch other Corpuſcles floating in the Air, as, by falling into the Eye, might hurt its tender Subſtance, or render it opaque and unfit for tranſmitting the Rays of Light.

§ 4. Amongſt all Creatures, Man alone is provided with Eye-brows; becauſe his Skin is ſmooth, and conſequently would eaſily allow ſuch Particles to ſlide alongſt it as might hurt the Eye, did not Nature provide againſt that Misfortune, by placing above it that thick Wood of Hairs.

§ 5. It is for the ſame reaſon that the *Caſſowar*, that ſtrange Bird, which, next to the Oſtrich, is the greateſt of all we know, being commonly five foot and a half in length from the End of the Beak to the Extremity of the Talons, and which has not been ſpoken of by any of the Antients, nor ſo much as known in *Europe*, till the Year 1597, that the *Hollanders* brought one from *India*; I ſay, it is for the ſame reaſon, that this Bird is provided with a Row of black Hairs, like a Demicircle at the Top of the Eye, raiſed like an Eye-brow, becauſe the Skin of its Head and Neck is ſmooth and without Feathers: But other Animals that have a rough plumaceous or hairy Skin, have no occaſion for Eye-brows, becauſe the Roughneſs of their Skin alone is ſufficient to anſwer their End.

§ 6. It is to be obſerved, that the Eye-brows do always bunch out conſiderably more than the Eye, becauſe of ſome Fat which is under the Skin in that Place, and becauſe of the Eminence of that Part of the frontal Bone which lies under them.

The frontal Bone has two conſiderable Eminencies, one above each Eye, formed by the Separation of the two Tables of the Skull, which leave Cavities betwixt them commonly called the *Frontal Sinuſes*. It is upon theſe Eminencies that the *Supercilia* are placed, and therefore they bunch out conſiderably above the Eye, which enable them the better to guard and defend it.

§ 7. There is yet another Mechaniſm provided by Nature by which the Eye-brows are excellently well fitted for defending the Eye, and that is, a Muſcle, which, by its Contraction, draws the Eye-brows obliquely downwards, and at the ſame time does corrugate them, and make them approach one another.

VOLTERUS COITER, in his *Obſervationes Anatomicæ*, is the firſt I find who has deſcribed this Muſcle. It ariſes from the great *Canthus* of the Orbit, preciſely where the *Os Naſi* is joined to the anterior *Apophyſe* of the *Os frontis*, from which Origin it goes obliquely upward, and terminates by a Tendon in the Skin about the Middle of the Eye-brows.

Some Anatomiſts (whoſe Opinion Cowper, in his *Myotomia Reformata*, ſeems inclined to favour) reckon theſe Muſcles only two oblique Elongations of the Frontals; but to me it appears of no conſequence, whether they be thought diſtinct Muſcles, or only ſuch Prolongations, provided that their Uſe be underſtood.

All Anatomiſts agree, that theſe Muſcles ſerve for pulling the Eye-brows obliquely downward, and at the ſame time for corrugating them, and making them approach one another: Their Origin and Inſertion, and the Direction of their Fibres, ſhew plainly that to be their Uſe; and therefore they are named *Corrugatores* vel *Depreſſores Superciliorum.*

§ 8. From the Action of theſe Muſcles pulling down and corrugating the Eye-brows, we receive a twofold Advantage: 1*mo*, The Eye is better defended againſt Duſt, Mots, and ſuch like external Injuries. Hence it is that every body, when walking abroad, or riding in a duſty Road, (as all of us have often done in Summer, when the Roads are dry); I ſay, every body in that Caſe pulls down his Eye-brows as much as poſſible, that he may the better cover his Eyes, and defend them againſt the Duſt and Mots with which the Air is then filled. 2*do*, A ſecond Advantage we reap from this Depreſſion of our Eye-brows, is the breaking and intercepting the Rays of Light, when the viſual Object is too luminous, or when the Eye is placed in too bright a Light. Hence in ſuch Caſes we alſo pull down our Eye-brows, that the Eye may be the better able to bear the Light, a Part of which is now intercepted by the depreſſed Eye-brows forming a kind of Shade on the Eye; and when the Eye-brows are not ſufficient for this End, as ſometimes happens when the Light is very ſtrong, we can aſſiſt them by applying our Hand to our Forehead, by which our Eyes are more effectually ſhaded, ſo as to enable us to bear the Light, which otherwiſe would dazzle and hurt our Eyes. But when there is no Danger to our Eyes, either from Duſt or Light, we pull up our Eye-brows, that none of the Light may be ſtopt, but that all of it may fall upon our Eyes; by which the Sight or Field of Viſion is enlarged, and all the Objects above the *Axis* of Viſion are now ſeen: whereas, when the Eye-brows were depreſſed, thoſe moſt remote from this *Axis*, being ſhaded by the Eye-brows, could not be perceived.

§ 9. The Muſcles which pull up our Eye-brows are the *Frontales;* they ariſe by a thin broad fleſhy Beginning, from the upper Part of the *Os frontis*, from whence deſcending, they are inſerted into the Skin of the Eye-brows, which they muſt therefore pull upward, that none of the Light may be ſtopt by them.

CHAP. II.

Of the Palpebræ *or Eye-lids, and the* Cilia *or Eye-laſhes.*

SECT. I. THE *Palpebræ* or Eye-lids are thoſe Parts which in time of Sleep cover our Eyes. They are two in number for each Eye, *viz.* the ſuperior and inferior. They are called *Palpebræ, a palpitando, quod palpitare et tremere videantur, propter citiſſimum et frequentiſſimum motum.*

§ 2. Both ſuperior and inferior are compoſed of five Membranes and a Cartilage. The *firſt* is the *Epidermis* or Scarf-ſkin, of which I need ſay nothing here. The *ſecond* is the *Cutis* or Skin, which is here very thin; and therefore, by *Ariſtotle* of old, it was ſaid to be *Cutis ſine carne*; and it is upon this account that ſo many Authors, following in this the Doctrine of GALEN, have affirmed, that when it is cut, it does not coaleſce. It is exceeding ſoft and laxly extended over the Eye-lids, that it may the better accommodate itſelf to the convex Figure of the Eye, and that it may be moved to and again thereon with the greater Facility. Hence alſo it is, that in Fowls there are never any Feathers to be found upon their Eye-lids, becauſe their Roots would have hurt the tender Subſtance of the *Cornea* upon their leaſt Motion. At the Extremity of the Eye-lids this Skin does not terminate, but is turned over to their Inſide, by lining which it forms the fifth and inner Membrane of the Eye-lids; which inner Membrane, at the Edge of the Orbit, folds back again over the outward Face of the Eye above the *Conjunctiva* to which it is cloſely adherent, and which is of ſome Conſequence to be remembered in curing ſome of the Diſeaſes of the Eye.

§ 3. This Skin is pierced at the Edge of the Eye-lids, for the Paſſage of ſome Hairs called *Cilia, quia Oculos celent ac tueantur*. They ſerve as a *Paliſado* to preſerve and ſhade the Eyes as the Eye-brows do, and to hinder any Filth or Flies from getting into them. Hence it is to be obſerved, that when thoſe Hairs are loſt, a Symptom which frequently follows a malignant Small-pox and Ulcerations of the Edge of the Eye-lids, the Sight is conſiderably impaired. GALEN of old obſerved this; but his Philoſophy could not account for it. All he ſays amounts only to this, that thoſe Hairs direct the viſual Spirits or the Rays that ſhine forth from our Eyes. But the true Reaſon is, that thoſe Hairs, by breaking and intercepting the adventitious Rays that come from the Heavens, or other Objects above the *Axis of Viſion*, render the inward Eye more dark; whence the Picture on the *Retina* becomes more clear and diſtinct:

Juſt as in a *Camera Obſcura*, the Picture is always the moſt diſtinct and lively, when no Rays are allowed to enter it but thoſe that come from the Object forming the Picture.

From this we may ſee, why the Sight is commonly beſt when thoſe Hairs are black, and worſt when they are very fair or white; for as black Eye-laſhes are the moſt proper for ſhading the Eyes, ſo there is no Light reflected from their inner Side, which by entering the Eye might efface or weaken the Picture on the *Retina*; whereas white Eye-laſhes reflect Light copiouſly into the Eye, from which this Picture becomes faint and imperfect. We have a beautiful Hiſtory to this Purpoſe recorded by PHILIPPUS MONALTUS (*Opticæ ſuæ, lib.* 4. *cap.* 8.) which, becauſe of its ſingularity, I ſhall ſet down in his own Words. *Ulyſſipponæ* (ſays he) *in domo perilluſtris S. Franciſci Rolini novi quendam, cui oculi glauciſſimi; capitis, ſuperciliorum, palpebrarumque pili ab ortu ſumme candidi, quales etiam per pubertatem barbi pili prodierunt; per juvenilem vero inclinantemque ætatem, omnium albedo magis magiſque remiſſa: Puer is adoleſcenſque per diem calligabat; erat per noctem perſpicacior: Ætate provectior diurnam hebetudinem, nocturnamque perſpicaciam ſenſit manifeſte deficere. Cum idem apud Mauritanos captivus detineretur; ex illis quidem (ſeu ut illuderent capto, ſeu experiundi gratiâ) atro colore ipſi palpebrarum pi-*

los intinxere; quo facto confeſtim ſe ipſo perſpicacior redditus eſt; atramento deterſo, minus perſpicax.

This is a very curious and uncommon Caſe; and tho' the Author does not account for it, yet from what has been ſaid, it admits of an eaſy Solution: For as black Eye-laſhes, for the Reaſons above noticed, are better qualified for darkening the inward Eye than white ones; it can be no Surpriſe that this Youth ſhould have had his Sight improven by having his white Eye-laſhes dyed black; and it is as little ſurpriſing that, in his younger Years, and when a Boy, his Sight was remarkably more dim and confuſed in Day-light than towards Night; for at that Time his Eye-laſhes being extremely white, they behoved to reflect a good deal of the bright Day-light into his Eyes, more perhaps than they could well bear; and beſides this, the reflected Light, by mixing with the Light coming from the Object in view, behoved to make its Picture on the *Retina* more dim and confuſed. On both theſe accounts, his Sight behoved to be worſe in bright Day-light than towards Night, when leſs of this adventitious Light was reflected into the Eye; but as he advanced in Years, his Eye-laſhes becoming leſs white, would reflect leſs Light into his Eyes; whence the Difference in his Sight by day and by night behoved gradually to diminiſh, and come nearer to what is common and natural.

There is a remarkable Story to the ſame Purpoſe recorded by my ingenious Friend the learned Dr. RUSSEL, in his *Natural Hiſtory of Aleppo*, a Book much to be valued for the many uſeful Obſervations he has given us on the *Plague* and other *Epedimical Diſeaſes* of that Country. This learned Gentleman there informs us, "That, upon a Principle of ſtrength-"ning the Sight, as well as an Ornament, it is "become a general Practice among the *Turkiſh* "Women to black the Inſide of their Eye-"lids, by applying a Powder called *Iſmid*; "and that this is ſometimes practiſed by "the Men, but is then regarded as fop-"piſh."

This memorable Story ſerves to confirm that juſt now mentioned from MONALTUS, and at the ſame time ſhews, that it was not out of Wantonneſs that the *Turks* dyed that Captive's Eye-laſhes, as MONALTUS ſuppoſes, but from the Experience they had of improving the Sight by it; and however trifling or uſeleſs this Practice of blacking the Eye-lids may be looked on by ſuch as have not fully conſidered the Matter, yet it is obvious that the Sight muſt receive ſome Benefit from it; ſeeing leſs Light will be reflected into the Eye by the Edge of the Eye-lids, from which the Pictures on the *Retina*, and the Viſion cauſed thereby, muſt be more perfect and diſtinct. Thoſe whoſe Eyes are extremely good, and whoſe

Occaſions ſeldom call them to be attentive to minute Objects, as they have no need to black their Eye-lids, ſo they may indeed be inſenſible of any Benefit ariſing from it. But ſuch as have a weak Sight, or who are employed in Sewing, or ſuch like ſubtile Work, cannot but be ſenſible of the Improvement made in their Sight by this black Colour. This Method of improving the Sight, I imagine, was at firſt diſcovered by chance; but after it was diſcovered, it needs be no Surprize that it became general amongſt thoſe Women, on account of the more ſubtile Work they might have occaſion to be employed in; more eſpecially that they found that it was looked on as an Ornament. And it is as little ſurpriſing, that, when the Men, without Neceſſity, and contrary to the Cuſtom that has obtained among them, imitate the Women in this Practice, ſuch are regarded as foppiſh, as the Doctor informs us. But to return to the Membranes of the Eye-lids.

§ 4. The *third* Membrane of the Eye-lids is the *Membrana adipoſa* or *celluloſa*, which is likewiſe very thin, becauſe there is ſcarce any Fat contained in its *Cellulæ*. It is this Membrane which ſwells ſo exceſſively in the Small-pox, from the Depoſition of an acrid *Serum* into its Cellules, which are thereby vaſtly extended.

The *fourth* Membrane of the Eye-lid is carnous, and is nothing but an Extenſion of the *orbicular Muſcle.* At the Extremity of this Membrane is attached a ſoft thin broad Cartilage called *Tarſus, propter ſiccitatem, quod carnis ſit expers;* for which reaſon the Back of the Foot bears the ſame Name. Its figure is like the Segment of a Circle; it is convex in its Outſide, but concave on the other next the Eye, by which means it keeps the Eye-lids, to whoſe Extremities they are attached, equally extended over the Eye, and diſpoſes them to be moved to and again thereon without Wrinkles. Theſe Cartilages are covered with the Skin externally, and with the inner Membrane of the Eye-lids internally. Upon their inner Side, next the Eye, there is a Range of ſmall ſebaceous Glands, called from their firſt Diſcoverer *Glandulæ Meibomiæ.* They ſeparate a ſort of Balſam from the Blood which they ſend to the inner Edge of the Eye-lids by excretory Ducts which open thereon. Theſe Glands, together with their Excretories, are well deſcribed by the famous MORGAGNI in his *Adverſaria,* who therefore deſerves to be conſulted thereon. The Uſe of this Balſam is to defend the Edges of the Eye-lids from being excoriated where they ſtrike upon one another, and to keep them from Concretion in time of Sleep, as ſometimes happens, when, from any Diſeaſe in theſe Glands, this Ointment is either wanting, or has loſt its balſamic

Quality; a Caſe which frequently occurs in Practice.

The *fifth* and laſt Membrane of the Eye-lids is exceeding thin and delicate. It lines the Inſide of the Eye-lids. Some will have this Tunicle to be a Production of the *Perioſteum*, which lines the Orbit internally: But to me, as I have hinted before, it appears rather a Production of the Skin which covers the Eye-lids externally, and that for theſe Reaſons:

1*mo*, Becauſe they are both ſo cloſely conjoined and confounded together at the Edge of the Eye-lids, that they cannot be ſeparated without cutting their Subſtance; which could ſcarcely happen, were they diſtinct Membranes only joined together.

2*do*, A *ſecond* Reaſon may be gathered from what RUYSCH obſerves, in his 10th *Theſaurus*, concerning the Structure of this inner Membrane. He there tells us, that over all its internal Surface, next the Eye, it abounds with *nervous Papillæ*, by means of which it is endowed with ſuch an exquiſite Senſe, that the leaſt Particle of Sand getting betwixt it and the Eye, occaſions an unſupportable Pain. Theſe *nervous Papillæ* with which this Tunicle abounds, and which render it ſo ſenſible, eſpecially when inflamed, ſeem to me a very ſtrong Argument for its being thought a Continuation of the Skin of the Eye-lids, rather than of the *Perioſteum* lining the Orbit, which never has any of thoſe *nervous Papillæ* with which the Skin and the inner Membrane of the Eye-lids abound.

And, *laſtly*, when any of the Eye-lids happen to be renverſed, ſo as to have their inner Surface expoſed to the Air, as in the Diſeaſe called *Ectropion*, this Membrane at laſt becomes dry, and appears altogether like the Skin, as MAITRE JEAN well obſerves (*Maladies de l'Oeil, chap.* 2.) Nor do I ſee how this Tunicle, if it were a Production of the *Perioſteum*, could be conceived to fold back again at the Edge of the Orbit, and to extend itſelf over the outward Face of the Eye above the *Conjunctiva*, as it moſt certainly does, and from which it may eaſily be ſeparated, as has alſo been obſerved by MAITRE JEAN (*ibid: chap.* 6.) and other Authors of Credit.

§ 5. The Uſe of the Eye-lids is to cover the Eye, to defend it againſt ſtrong Light and other external Injuries, and, by their quick and frequent Motion, to diffuſe equally over the whole *Cornea* the Liquor which comes from the *Glandula lachrymalis*, by which means the Eyes are continually moiſtened, waſhed, cleaned, poliſhed, and made more tranſparent, for the better tranſmitting the Rays of Light.

§ 6. That our Eyes may ſuffer from ſtrong Light, as well as from groſſer Matter, is obvious to every one's Experience, and is further confirmed by that memorable Story of XENOPHON's Troops, many of whom were blinded by the bright Light reflected from the Snow thro' which they were obliged to march. This Story is recorded by GALEN *de Uſu Partium*, *Lib.* x. where, in Confirmation of the ſame Doctrine, he alſo takes Notice of thoſe miſerable Captives whom *Dionyſius* the Tyrant of *Sicily* uſed to bring forth from the dark Dungeon in which they were confined, into a white well lighted Room; and who, not being able to bear this ſudden Tranſition from Darkneſs to ſo bright a Light, were thereby immediately blinded.

The ſame antient Author there alſo obſerves, that no body can look ſtedfaſtly on the Sun for any Time together, without loſing his Sight; which Misfortune, he ſays, has happened to many, who, from a Deſire to ſee the Progreſs of an Eclipſe, were ſo imprudent as to keep their Eyes fixed on this firy Globe for a conſiderable Time, by which they were ſoon blinded; and ſuch as were not blinded had their Sight ſo much hurt, that they recovered it with Difficulty.

The famous Story of ATTILIUS REGULUS is another Proof of what our Eyes may ſuffer from ſtrong Light. This noble Conſul of *Rome*, ſo famous for his Faithfulneſs in keeping his Word to his Enemies, tho' it were to the Loſs of his Life, having been taken by the *Carthaginians* in the firſt *Punic* War, was ſent to *Rome* to adviſe an Exchange of Priſoners; but he perſuaded the contrary in the Senate, and therefore, upon his Return to *Carthage*, for a Puniſhment, they cut off his Eye-lids, and expoſed him to the Sun, whoſe Light he could not long bear without being blinded; as FABRICIUS *ab Aquapendente* obſerves from the *Roman* Hiſtorians.

From theſe Hiſtories we may ſee of what Uſe our Eye-lids are in defending our Eyes againſt ſtrong Light, and why, when it is very ſtrong, we ſhut our Eye-lids ſo as to leave open only a very ſmall Slit, by which Action a Part of the Light is intercepted, which by entring our Eyes might dazzle them, and hurt our Sight.

And it is for the ſame Reaſon, that thoſe who paint on white Leather, eſpecially when their Sight is weakened by an *Ophthalmia*, or ſome ſuch Diſeaſe, find it neceſſary to place hard by the luminous Object dark and green Colours, towards which the Eyes being turned from time to time, they are thereby refreſhed and ſtrengthened; for being relieved from the Pain and Fatigue they ſuffered from the luminous Object, they ſoon recover Strength again, ſo as to be able to bear the Light of the Object for ſome Time longer

§ 7. Cruſtaceous Animals, ſuch as the *Locuſta*, *Gammarus*, *Pagarus*, *Cancer*, *&c.* want Eye-lids; becauſe in them, in place of being uſeful or neceſſary, they would have been hurtful, and an Impediment to their Sight; for, had Nature extended their hard cruſtaceous Skins over their Eyes in form of Eye-lids, they could not have been moved to and again upon their Eyes; at the ſame time, were it poſſible they could be moved, they would neceſſarily hurt the tender Eye, in place of defending it: Therefore provident Nature has wiſely contrived another Method by which their Eyes might be ſecured from external Injuries, and that is the Hardneſs of the *Cornea*, which in theſe cruſtaceous Creatures exactly reſembles the Horn of a Lantern, and therefore is not to be hurt by ſuch Particles as their Eyes are commonly expoſed to.

FABRICIUS *ab Aquapendente* affirms, that this horny Hardneſs obtains not only in cruſtaceous Animals, but alſo in all others, without exception, that want Eye-lids for guarding and defending their Eyes. *In gammaris piſcibus*, (ſays he) *de Ocul. p.* 1. *cap.* 2. *et iis quorum oculus palpebra non tegitur, ita dura eſt cornea, ut exacte cornu laternarum rigiditatem quoque præ ſe ferat.* Theſe are FABRICIUS's words. But in this I apprehend he is miſtaken; for tho' I do not deny that in Animals that want Eye-lids the *Cornea* is commonly much firmer and harder than in Man, and other Creatures that are provided with Eye-lids; yet in many ſuch

Animals we find that its Hardneſs is far inferior to that of the Horn of a Lantern.

There is yet another Mechaniſm by which the Eyes of cruſtaceous Animals are ſecured, and that is, deep *Sinuſes* into which, as into a ſafe Chamber, they can retract their Eyes upon the Approach of any extraordinary Danger, or when they incline to ſleep; as has been excellently well obſerved by the ſame FABRICIUS in the above quoted Treatiſe *de Oculo*:—No Animal can ſleep eaſily while the Light is ſtrong, unleſs its Rays be kept from falling upon their Eyes:—This therefore is one Reaſon why Animals that are expoſed to bright Light are provided, ſome with Eye-lids, ſome with deep *Sinuſes*, by means of which they can ſhade their Eyes, for intercepting the Light which otherwiſe would ſoon diſturb their Reſt.

§ 8. But moſt Fiſhes are deprived both of Eye-lids and theſe *Sinuſes*, becauſe they have no occaſion for either of them: For ſince they conſtantly reſide in Water, their Eyes are not expoſed to Air, Smoak or Duſt, which would dry, hurt, and obfuſcate the Eyes of Land-Animals, were they not perpetually moiſtened, cleaned and poliſhed by the lachrymal Juice and Motion of the Eye-lids; and moreover, the *Cornea* of Fiſhes being commonly more firm and hard than in Land-Animals, can receive no Hurt from ſuch Particles as their Eyes are uſually expoſed to. Neither in Sleep have they occaſion to cover their Eyes; becauſe the Water, in which they are, intercepts a Part of the Light, and renders it leſs fit to diſturb the Reſt by its Brightneſs: and beſides, when they would ſleep, they can deſcend into the Bottom of the Water, or hide themſelves among Stones, Herbs, or Mud, ſo as to anſwer all the Ends of Eye-lids.

§ 9. But tho' Fiſhes commonly want Eye-lids, yet it has ſince been found, that Flounders, Plaiſe, Soles, and all flat Fiſhes, are excepted from this Rule, and have Eye-lids wherewith they can cover their Eyes as need requires. The Reaſon of which ſeems to be, that this Sort of Fiſh are not ſo Nimble as others in ſwiming, being only able to move their Tails, their chief Inſtrument of Speed, upwards and downwards: Wherefore theſe Fiſhes, in a Storm, do not betake themſelves to the deep Sea, at the Bottom of which they would be in Safety; but they dig themſelves Holes in the Sand, as I have been informed; which ſecures them from being thrown upon the Beach or Strand. Now, if they had not Eye-lids, the ſharp Points of Sand, whilſt they are making their Beds, would ſcratch and cut the Tunics of their Eyes, whereby the tranſparency thereof would be deſtroyed, and conſequently theſe Fiſhes would become Blind;

which is an additional Proof how perfect every Creature is, in its own Species.

§ 10. And with regard to Inſects, I might here obſerve, that altho' the Hardneſs and Firmneſs of the *Cornea* is in them ſo good a Guard to their Eyes, as to render Eye-lids unneceſſary; yet theſe Creatures are obſerved to have ſomething analagous to Eye-lids, wherewith they clean and wipe their Eyes from time to time. The Reaſon of which is, that Inſects reſide conſtantly in Air, which, by means of the Smoak, Duſt and Moats with which it abounds, would ſoon obfuſcate and tarniſh the tranſparent Eye, were it not thus wiped and cleaned as need requires.

The Inſtruments employed in this Work, are the Fore-legs and the *Antennæ* or Feelers: But whatever the Uſe of the *Antennæ* may be in cleaning the Eyes, they are moreover, in all probability, a good Guard to the Eyes and Head in their Walk and Flight, enabling them, by the Senſe of Feeling, to diſcover ſuch Annoyances, which, by their Proximity, may perhaps eſcape the Reach of their Eyes and Sight; for it is manifeſt, that Inſects clean their Eyes with their Fore-legs as well as *Antennæ*; and conſidering that as they walk along, they are perpetually feeling and ſearching before them with their Feelers or *Antennæ*; I cannot help thinking, that, beſides wiping and cleaning the Eyes, the Uſes above named ſhould alſo be admitted; eſpecially that it is extremely probable that the Eyes of Inſects do not change their Conformation, and adapt themſelves to various Diſtances, but, continuing always the ſame, are fitted only to ſee diſtantial Objects, but not ſuch as are very nigh; which Inconvenience the Feelers obviate, leſt it ſhould be prejudicial in occaſioning the Inſect to run its Head againſt any thing in its Way.

And that this rather than the wiping of the Eyes is the chief Uſe of the Feelers, is further manifeſt from the *Antennæ* of the *Fleſh-fly*, and many other Inſects, which are ſhort and ſtrait, and incapable of being bent unto, or extended over the Eyes. As alſo, from others enormouſly long, ſuch as thoſe of the *Capricorni* or Goat-chaffers, Cadew-fly and divers others, both Beetles and Flies. But to return:

§ 11. As Animals having firm hard Eyes commonly want Eye-lids, ſo, on the contrary, all Animals that have a ſoft, tender and delicate *Cornea*, and who conſtantly reſide in the Air, as Man, Quadrupeds and Fowls, are always provided with Eye-lids, wherewith, in time of Sleep, they cover their Eyes, partly to defend them againſt external Injuries, and partly to intercept the Light, which, by falling into their Eyes, would greatly diſturb their Reſt; but, at other times, as has been before obſerved, theſe Eye-lids are moved to and again

gain upon the Eyes, for cleaning, waſhing and poliſhing the *Cornea*; and which is remarkable, this Motion is ſo very quick, that it does not in the leaſt hinder our Sight.

Every body knows, that if a burning Coal be nimbly moved round in a Circle with Gyrations continually repeated, the whole Circle will appear like Fire. The Reaſon of which is, that the Senſation of the Coal, in the ſeveral Places of that Circle, remains impreſſed on the *Senſorium*, until the Coal return again to the ſame Place; for the Motions excited in the Bottom of the Eye by Light, and thence propagated to the *Senſorium*, are of a laſting, and conſequently of a vibrating Nature; and therefore, if our Eye-lids take no longer time to paſs and repaſs upon our Eyes, than what the Coal of Fire takes to go round, the Impreſſion made in the Bottom of our Eye by any Object will always continue, and ſuffer no ſenſible Interruption from the quick Motion of the Eye-lids paſſing over our Eyes; and this is the Reaſon why Nature has endowed our Eye-lids with ſuch a quick twinkling Motion.

§ 12. The Muſcles wherewith the Eye-lids are moved are,

1*mo*, The *Elevator Palpebræ ſuporioris*, ſometimes alſo called *rectus*. It ariſes by a ſmall fleſhy Beginning from the Bottom of the Orbit, near the Place where the optic Nerves pierce the *Cranium*, and paſſing above the

Attolens oculi, it becomes tendinous, as it marches over the Bulb of the Eye, whence growing ſtill broader and thinner, it is inſerted into the whole ſuperior Part of the Cartilage of the upper Eye-lid. When this Muſcle acts, it lifts up the Eye-lid, and diſcovers the Eye.

It is no eaſy matter to account for the groſs Miſtake into which not only GALEN, but the accurate VESALIUS himſelf, has fallen into, concerning this Muſcle, which tho' its Diſſection requires but little Art, yet by both theſe Authors, it is aſcribed to the Eye; for which REALDUS COLUMBUS does juſtly reprehend them; but at the ſame time he commits no leſs an Error himſelf, in ſuppoſing, contrary to what GALEN and VESALIUS teach, that the *Obliquus ſuperior* belongs to the Eye-lid.

2*do*, The Eye-lids are brought together to ſhut upon the Eye by another Muſcle, which, becauſe of its Figure, is called *Orbicularis*. This is a thin fleſhy Muſcle, about two Fingers broad, whoſe Fibres do circularly environ and cover the Eye-lids, and are not adhering to any Bone from which we may derive their Origin except the ſuperior Part of the great Bone of the Noſe. This Muſcle, like the Sphincters of other Parts, conſtringes the Eye-lids, and brings them together over the Eyes; and likewiſe when it contracts with a more than common Force, it preſſes the Globe of the

Eye inwards; by which means the *Glandula lychrymalis* is compreſſed, and the Tears contained therein are ſqueazed out in greater Plenty upon the Eye, for moiſtening and cleaning it, as occaſion requires.

GALEN, and the antient Anatomiſts, together with VESALIUS, RIOLANUS, SPIGELIUS, *&c.* do divide this Muſcle into two, *viz.* the *Semicircularis ſuperior* and *inferior*, and make the ſuperior to ariſe from the great *Canthus* and ſpread over the ſuperior Eye-lid, and terminate at the leſſer *Canthus*; and in like manner to the inferior, which covers the under Eye-lid, they give the ſame Origin and Termination. The Reaſon of which Diviſion, is not ſo much that they pretend to have diſcovered two Muſcles, as becauſe they receive different Nerves coming from different Places, and becauſe they have ſometimes obſerved, in the *Convulſio canina*, that the inferior Eye-lid is rigid and immoveable, while the other is well, and in its natural State: But theſe Reaſons do not appear ſufficient for thus dividing this Muſcle; for, as COWPER well obſerves, there appears no diviſion of Fibres at the external Angle; and beſides ſeveral other Muſcles, and particularly ſome of thoſe belonging to the Noſe, have different Nerves, as well as the *Orbiculares palpebrarum*, as BARTHOLINE and others obſerve.

The under Eye-lid has but a very obſcure Motion, and therefore has no need of a particular Muſcle for opening it. The elaſtic muſcular Fibres, which from it are ſpread upon the Cheeks, and which have been well deſcribed by EUSTACHIUS and COWPER, being ſufficient for that End.

§ 13. It is to be obſerved, that tho' all Animals that are provided with Eye-lids have a Power of moving them to and again upon their Eyes for the Purpoſes above noticed, yet, in different Animals, they are differently moved; ſome moving the ſuperior more than the inferior, and others moving the inferior more than the ſuperior. This ſeems at firſt View to be a Matter of no great Conſequence, and ſcarce worth inquiring into; yet Nature, which does nothing in vain, has not without very good Reaſon made the Eye-lids of different Animals thus differently moveable.

Man, and the greateſt Part of Quadrupeds, that is, thoſe of the *viviparous* Kind, move both Eye-lids; but the Motion of the under Eye-lid is very obſcure: Whereas all *oviparous* Quadrupeds, ſuch as the Tortoiſe, all Birds, and in general, all Animals that look much down, and ſeek their Aliment from the Ground, have the inferior Eye-lid greatly more moveable than the ſuperior. The Reaſon of which is ſo well expreſſed by FABRICIUS *ab Aquapendente*, that it may not be diſagreeable to read it in his own

Words. *Illa animalia* (ſays he, *de Ocul. p.* 3. *cap.* 13.) *quæ prona incedunt, quæque a terra almoniam capiunt, ut teſtudines, &c. palpebram inferiorem mobiliorem ſuperiori habent, ut oculus magis tegatur aperiaturque, ea parte qua oculorum uſus et cuſtodia poſtulat, hoc eſt, qua magis ſunt offenſionibus expoſiti, aut qua magis venire offenſiones periculum eſt, aut qua magis oculum offendi ab extrinſecus occurſantibus certiſſimum eſt, ut a ſpinis, feſtucis, pulvere, et aliis id genus offendiculis, quæ magis a terra et ex inferiore parte accedere poterant. Aves autem, ſive pennata animalia, ita palpebram inferiorem habent mobilem, ut ſuperior parum omnino moveri videatur; quod hæc magis adhuc, ſive in terra degant ſive in aere, oculos ad terram inclinatos obtineant, a qua parte offenſiones ad oculum venire periculum eſt.*

§ 14. Beſides theſe Eye-lids, provident Nature has contrived another Fence and Security for guarding, defending and cleaning the Eyes of ſuch Animals as the Neceſſities of Life oblige to frequent Trees and Buſhes, as Birds; or Hedges and long Graſs, as Horſe, Cows, Frogs, and other Quadrupeds. This aditional Guard goes commonly under the Name of *Membrana nictitans*, or internal Eye-lid, and is nothing but a moveable Membrane placed next to the *Cornea*, over which it paſſes to and again under the Eye-lids, the better to defend and preſerve the Eyes of theſe Animals that are frequently among Trees, Buſhes or Graſs;

which is the only Uſe that Dr. WILLIS, and the moſt part of our *Engliſh* Writers, aſcribe to this Eye-lid.

§ 15. But the *French Academiſts*, who have been very diligent in examining this Eye-lid, and to whom we owe the Knowledge we have of its Structure and Mechaniſm, finding it not only in Creatures that frequent Trees, Buſhes, and Graſs, but alſo in all Animals expoſed to Air that want Hands for rubbing their Eyes, are of Opinion, that its principal Uſe is, not ſo much to defend the Eye from being hurt by Graſs, or the Leaves of Trees and Buſhes, as, in conjunction with the other Eye-lids, to clean and wipe the *Cornea*, and keep it from drying and becoming leſs tranſparent; for which End it indeed appears excellently well diſpoſed; for it moves tranſverſly from right to left, and from left to right, over the *Cornea*, while the other Eye-lids ſhut and open for the better wiping and cleaning the Eye, every way; and which is remarkable, to this Eye-lid, as may be ſeen in all large Birds, is attached the *lachrymal Gland*, whoſe Excretory (for in Birds there is but one) penetrating above half way thereupon, upens opon the Eye about the Middle of this Eye-lid; which is evidently done, to ſpread a Liquor over the whole *Cornea*, for the better waſhing and cleaning it, when this Eye-lid paſſes and repaſſes, as it is obſerved to do every moment.

In Calfs, this *lachrymal Gland* has two excretory Ducts, which open upon the Eye, one on each Side of that Cartilage, which is peculiar to this Animal, as has been obſerved by STENO, VARHEYEN, and others. This Cartilage, according to ſome Anatomiſts, ſerves to facilitate the Motion of that Membrane wherewith they nictitate. *In oculo autem bubulo* (ſays the learned DIEMERBROECK, *Anatom. lib.* 3. *cap.* 13.) *præter iſtam carunculam, particula quædam calloſa et duriuſcula, verſus oculum plane lævis, exteriore parte aliquantulum aſpera, in interno angulo reperitur, membranæ qua nictitant motum faciliorem præbens.* Theſe are DIEMERBROECK's Words, which I thought proper to mention here, becauſe the Uſe of this Cartilage is ſeldom touched on by Anatomiſts. But beſides this, it ſeems ſtill to have a further Uſe, to wit, by ſtrengthening this Eye-lid, it enables it the better to guard and defend the Eyes of this Animal, who being formed to gather its Food from among Thorns and Buſhes, has occaſion for a ſtronger Fence and Security for guarding and preſerving its Eyes, than moſt other Creatures.

§ 16. Animals that have Hands with which they can defend their Eyes, and by rubbing them can expreſs the Liquor contained in the *lachrymal Gland* for waſhing and cleaning them, which is known by Experience they do with good Succeſs when the Sight is any way darkened, or when the Eyes ſuffer any Pain or Itching; I ſay, Animals that have Hands for guarding and rubbing their Eyes, have no need of this internal Eye-lid. Hence it is that Man, and the Ape, are the only Animals expoſed to Air and Duſt, in whom this Eye-lid is found wanting.

§ 17. Fiſhes alſo commonly want this Eye-lid, becauſe their Eyes are in no Danger of being dried by the Air, nor have they occaſion either to defend or clean their Eyes from Filth, Duſt or Smoak, to which they are never expoſed; and beſides, as we have ſaid before, their *Cornea* is firm and hard, and ſometimes almoſt cartilaginous, and therefore is not to be hurt by ſuch Particles as their Eyes are expoſed to. But all aquatic Animals, that come out of the Water and ſtay ſome time upon Land, as the Sea Calf is obſerved to do, are provided with this Eye-lid, for the ſame Reaſon that Land-animals are, *viz.* becauſe they want Hands to rub their Eyes, and expreſs the Humidity contained in the Glands, for waſhing and cleaning them as occaſion requires.

§ 18. The Structure of this Eye-lid, and the Mechaniſm by which it is moved, tho' exceeding beautiful and induſtrious, has not been noticed by any I know of, except ſome few of the Gentlemen of the Royal Academy of Sciences. From them therefore, for your Entertainment,

tainment, I ſhall, in as few Words as poſſible, deſcribe both.

This Eye-lid is nothing elſe but a moveable membranous Part, which, when extended over the *Cornea*, is of a triangular Figure; but has the Figure of a Creſcent when drawn back again into the great Corner of the Eye for uncovering the *Cornea*. One of its Sides, which may be called its Baſe, is in its whole Length attached towards the inward Angle of the Eye to the *Tunica Sclerotica*, and takes up about a third, or a little more of its Circumference; the other two Sides are not at all attached to any Part, but leave this Membrane at liberty to be extended over the Eye, or to be retracted from off the Eye into its great Angle, as need requires. That Side which is towards the little Corner of the Eye, and which is moveable, is commonly reinforced with a Border, which ſupplies the Place of the *Tarſus*, and is black in moſt Quadrupeds. In Cows, a Part of this Membrane is cartilaginous, as STENO obſerves, which may ſerve not only for facilitating its Motion, as has been noticed before from DIEMERBROECK, but alſo for ſtrengthning it, that it may the better guard and defend the Eyes of this Animal, who, when it gathers its Food from amongſt Thorns and Buſhes, has occaſion for a ſtronger Fence and Security for its Eyes than moſt other Creatures.

There is no other Mechaniſm for retracting this Eye-lid from before the Eye, but the Elaſticity of the Fibres of which it is compoſed. They ariſe from its *Baſis*, where it is attached to the great Angle of the Eye, and are inſerted into its *Tarſus*, or that Side next the ſmall Angle; which they muſt therefore retract towards the great Angle, whenever the extending Force ceaſes to act.

This Eye-lid is extended over the Eye by the joint Contraction of two Muſcles, whoſe Contrivance and Diſpoſition is truly ſurpriſingly curious and beautiful.

The firſt ariſes, by a broad fleſhy Beginning, from the *Sclerotica* towards the great Corner of the Eye, behind the Attachment of this Eye-lid; and contracting itſelf gradually as it goes towards the optic Nerve, near that Nerve it forms a ſmall cord-like Tendon; which Tendon paſſing under the optic Nerve, upon which it makes an acute Angle, pierces the Tendon of the other Muſcle, which ſerves it for a Pully, on which it is bent; and, after it has pierced this Tendon, it goes obliquely upward and inward upon the Backſide of the Eye, to inſert itſelf to the moveable Corner of this triangular Membrane, at the upper and inward Part of the Eye, near the Edge of the Orbit.

The ſecond Muſcle riſes from the Globe of the Eye towards the little Angle, and ends by a Tendon near the optic Nerve, having its tendinous End pierced with a Hole, thro' which as a Pully the Tendon of the other Muſcle paſſes, and there forms an Angle, in which the optic Nerve is contained, tho' not compreſſed or touched, becauſe of this Pully, which keeps the Tendon back.

From this curious Diſpoſition of the Muſcles, it is eaſy to conceive, how this internal Eye-lid is extended over the *Cornea* far enough to cover all the *Pupil*, tho' the Muſcles themſelves are contained in a ſmall Space. Every Body knows, that the Contraction of all Muſcles is only in a certain given Proportion to their Length; and therefore that this Eye-lid might be drawn far enough over the *Cornea*, Nature was obliged to make uſe of a long Muſcle, which could not be contained in ſo ſmall a Place as the Orbit, without being bended or inflected; and therefore the firſt Muſcle is bent upwards near the optic Nerve, making an acute Angle, where it paſſes thro' the perforated End of the other Muſcle, by which means its Action is greatly increaſed.

But its Action is yet more increaſed, by the Contraction of the ſecond Muſcle itſelf, which muſt draw the Cord or Tendon of the other Muſcle which paſſes thro' it, thro' a Space double of what it moves itſelf; and thus the *Membrana nictitans* is extended far enough to cover the whole *Cornea*, tho' its Muſcles are contained in a ſmall Space.

But, that the Diſpoſition of this Eye-lid, and the Mechaniſm by which it is moved, may be the better underſtood, ſee PLATE I. *Fig.* 1. and 2. which I have cauſed to be copied from Monſ. PERRAULT.

FIG. 1. repreſents four Globes of the Eyes of Birds, of which the two firſt are ſeen from before, and the other two are ſeen from behind.

A B D the Membrane forming this Eye-lid drawn back towards the great *Canthus.* A D its immoveable Baſe; B the Extremity of the Tendon which draws this Membrane over the Eye; E F G this ſame Membrane extended over the Eye by the Motion which the Tendon B makes in going to C in the firſt Eye, which is G in the ſecond.

H I K L the Eye ſeen from behind, in which the Membrane is drawn from over the *Cornea*, and brought into the *great Canthus* of the Eye. H the End of the Tendon marked B and G; L the Origin of the Muſcle whoſe Tendon paſſes thro' K to go towards H; I K the other Muſcle whoſe Tendon is pierced at K, to ſerve as a Pully to the firſt Muſcle.

N O P, the ſame Eye ſeen from behind, for underſtanding how the Muſcle O N, by contracting, while the Muſcle Q contracts at the ſame time, makes the Tendon H move to M, that is, from P to N, or, which is the ſame thing, from B to C, or from R to G, by which means this Membrane is extended over the *Cornea.* And it muſt be ſuppoſed, that, by its elaſtic Contraction, it is drawn back into the *great Canthus*, when theſe Muſcles ceaſe to act.

Fig. 2. Repreſents this ſame internal Eye-lid ſeparated from the Eye. A B the *lachrymal Gland*, C the *Ductus lachrymalis* opening upon the Eye.

§ 19. This Eye-lid is of different Colours in different Animals. The *French Academiſts* have obſerved, that, in the *Chamois*, or Gemp, which is a Quadruped of the Goat kind, it was red; and it is perhaps upon this Account that Albertus affirms that the *Chamois* has red Eyes.

In the Lion, they tell us, it is black; and it is probable, that the Reaſon of ſaying that Lions do ſleep with their Eyes open, is, that without ſhutting the Eye-lids, they can cover them with this thick black Membrane, which, as in Birds, can extend itſelf over all the *Cornea*, as has been obſerved by the ſame *Academiſts.*

Some Creatures have this Membrane tranſparent, ſo that it may paſs for a kind of moveable *Cornea* thro' which Objects are ſeen. This is particularly obſervable in Frogs, in whom alſo this Membrane is very ſtrong, and ſomewhat cartilaginous, for the better defending their Eyes: For they being amphibious Creatures, deſigned to paſs their Lives in watry Places, which for the moſt part abound with

Plants endowed with ſharp Edges or Points, and the progreſſive Motion of this Animal being not by walking, but by leaping, if his Eyes were not provided with ſuch a tranſparent Caſe, he muſt either ſhut them, and ſo leap blind-folded, or, by leaving them open, muſt run the Riſk of having the *Cornea* cut, pricked, or otherwiſe hurt; whereas, by extending this Membrane over the Eyes, they are ſecured from Danger, while at the ſame time the Sight is not hindered. This Membrane may be eaſily ſeen, by applying the Point of a Pin to the Eye of a Frog, whilſt his Head is held ſteady; for, to ſkreen his Eye, he will preſently cover it therewith, and afterwards withdraw it upon a Removal of the ſuſpected Danger.

In Cows, Part of this Membrane is cartilaginous, as STENO obſerves, which in that Creature ſerves for facilitating its Motion, and for enabling it the better to guard and defend the Eyes from being hurt by Thorns and Buſhes, from amongſt which they have ſometimes occaſion to gather their Food, as has been before obſerved.

The learned PERRAULT, in his *Mechanique des Animeaux*, takes Notice, that, in the Fiſh he calls the *Morgaſt*, which is a kind of *Galeus*, this Eye-lid is ſituated in the under Part of the Eye, from which it is raiſed by one ſingle Muſcle, and is again retracted by its own proper

Fibres. And I am greatly miſtaken, if the Cat has not two of theſe nictitating Membranes, one in each Angle of the Eye, which they can extend over their Eyes, ſo as to meet in the Middle of the *Cornea*. I had occaſion to obſerve this lately in a familiar Cat, which jumping upon my Knee, I took occaſion to look at its Pupil, and was ſurprized to ſee a Membrane of a dirty white Colour extend itſelf from each of the *Canthi* in the manner above noticed. This Cat being uncommonly tame, allowed me to keep its Eye-lids open with my Fingers, and, when it endeavoured to ſhut its Eye-lids, I ſaw thoſe Membranes extend themſelves over the *Cornea*, ſometimes more, ſometimes leſs, ſometimes not at all, and ſometimes ſo as to cover the whole *Cornea*, and meet in its Middle. This unexpected Appearance made me at firſt ſuſpect that I had miſtaken the Motion of the *Uvea*, by which the Pupil, which in Cats is an erect Figure, is ſhut and opened, for theſe Membranes; and therefore I examined it again, by which I was the more confirmed in what I had before obſerved; nor do I ſee how I could be deceived, tho' my Sight is not ſo good now as it has been; eſpecially that the *Uvea* of Cats is of a bright yellow Colour; whereas theſe Membranes were of a dirty white, like the Skin of labouring Country-people. But leaving this to be further inquired into by Anatomiſts, I ſhall proceed.

CHAP. III.

Of the Glandula lachrymalis.

SECT. I. BY the *lachrymal Gland*, I do not here mean that *Caruncle* or *Carnous Tubercle*, ſituate in the great Angle of the Eye, at the Entry into the lachrymal Sac, which by the Antients was called the *Glandula lachrymalis*, and whoſe Uſe in Man is not ſo much to furniſh the lachrymal Juice for moiſtening and cleaning the Eye, as to keep the *Puncta lachrymalia*, betwixt which it is placed, open, when the Eyes are ſhut, and to hinder the Tears from running down upon the Cheeks at the great Angle of the Eye: But, by the *Glandula lachrymalis*, I underſtand that Gland commonly called the *Glandula innominata*, which is ſituate behind the Conjunctive, upon the upper Part of the Globe, in a hollow *Sinus* formed in the Orbit itſelf, for the more convenient lodging of this Gland.

§ 2. This Gland is very large, and extends from the external Angle of the Eye to near its Middle; but it is not always exactly of the ſame Figure.

It is of the *conglobate* Sort, being made up of many ſimple Glands, which are ſo united together, as to form as it were ſeveral Lobes, ſometimes more, ſometimes fewer: From each Lobe there ariſes a ſmall Excretory, which opens upon the internal Side of the upper Eyelid. Theſe Excretories were firſt diſcovered in Sheep and Calves, by that accurate Anatomiſt NICOLAUS STENO, who alſo points out the Manner how they are to be found. (*Obſervat. de Gland. Oculor.*) In the Eye of an Ox, I have frequently ſeen eight or nine ſuch Excretories, each of which was large enough to admit of a Hog's Briſtle: But in Man theſe Excretories are ſo ſmall, that their Cavity can ſcarce be obſerved, and are like ſo many ſmall Lines going from the Gland to the internal Side of the Eye-lid where they terminate.

§ 3. Some Anatomiſts, MORGAGNI himſelf not excepted, have been ſo ſcrupulous, as to doubt whether theſe Lines are the Excretories of the *Glandula lachrymalis*, becauſe of their ſmallneſs, and the inviſibility of their Cavities. But with how little Reaſon, appears from the Analogy betwixt theſe Lines, and the Excretories of this Gland in Brutes; more eſpecially, that there is no other viſible Way how the Liquor ſecerned in this Gland can be conveyed from it: We therefore conclude, that the Uſe of this Gland is to ſeparate from the Blood that thin, tranſparent, ſaltiſh Liquor called *Tears*, and to ſend it by theſe line-like Excretories, which open upon the Inſide of the ſuperior Eye-lid, to the anterior Part of the Eye, for moiſtening, waſhing and cleaning it, which otherwiſe would ſoon dry, wrinkle and loſe its Tranſparency, by the conſtant Action of the Air, and the Duſt, Smoke and Moats contained in it.

§ 4. This Liquor is continually, tho' but in ſmall Quantity, poured out upon the Eye, and, by the twinkling Motion of the Eye-lids, is equaly diffuſed over the whole *Cornea*, for keeping it moiſt, clean and tranſparent; but, upon particular Occaſions, when our Eyes are any way darkened, or ſuffer any Pain or Itching, by being long expoſed to drying Winds, Smoak or Duſt, this Liquor is poured out upon the Eyes in greater Plenty; becauſe then, as has been before obſerved, the orbicular Muſcle contracts with a more than ordinary Force, and, by preſſing the Globe of the Eye inward, compreſſes the *lachrymal Gland*, and expreſſes the Liquor therein contained; and, when the Action of this Muſcle is not ſufficient for expreſſing a ſufficient Quantity of this Liquor, then we rub our Eyes with our Hands, which preſſes the Eye yet more inwards upon this Gland, and cauſes it yield its Liquor in greater Plenty. Whence we may ſee, why all Animals, whoſe Eyes are expoſed to the Injuries of the Air, and who want Hands for rubbing their Eyes, are provided with an interior Eye-lid, to which at the *great Canthus* is attached a certain Gland of the lachrymal Kind, which is peculiar to ſuch Creatures, and which opens by one or more Excretories upon the Eye, about the Middle of this Eye-lid; for this Eye-lid, by moving tranſverſly to and again upon the Eye, while the other Eye-lids ſhut and open, ſtretches and agitates this Gland, and expreſſes the lachrymal Juice contained in it, for waſhing and cleaning the *Cornea* as Occaſion requires, and is a ſufficient Proviſion for the Want of Hands, wherewith Man and the Ape rub there Eyes upon the like Occaſion, as has been before obſerved.

CHAP. IV.

Of the Puncta lachrymalia, Saccus lachrymalis, Ductus naſalis *and* Caruncula lachrymalis.

SECT. I. IN the *great Canthus* of the Eye there are two ſmall Holes, large enough to receive a Hog's Briſtle, called *Puncta lachrymalia*, which, and the Paſſage from them to the Noſe, however late the Diſcovery may be thought, GALEN was not ignorant of; as appears from the 11th Chapter of his 10th Book, *de Uſu Partium*, where the following Words, as they ſtand in the Tranſlation, are remarkable: *Quæ in palpebris ſunt tenuia admodum foramina,* *quæ paulo ſunt extra majorem angulum, ad naſum enim uſque pertinent, &c.*

§ 2. Theſe Holes are in the inner Side of the Eye-lids near their Edge, one in each Eye-lid: They lead to a ſmall membranous Bag called the *Saccus lachrymalis.* This Bag is likewiſe ſituated in the *great Canthus* behind the *Caruncula lachrymalis*, and lies upon the *Os Unguis.*

From the Bottom of this Sac there goes a ſmall Pipe or Canal, commonly called the *Ductus naſalis*, which is nothing but a Continuation of the lachrymal Sac. It pierces the *Os lachrymale*, and opens into the Noſe under the upper *Lamina* of the *Os ſpongioſum.* The lachrymal Sac, together with this Canal, reaching betwixt it and the Noſe, are nothing but an Extenſion of the inner Membrane of the Noſe, and therefore are glandulous as well as it; from which ſome of the *Phænomena* happening in the Diſeaſes of theſe Parts might eaſily be accounted for, were this a proper Place for ſuch Digreſſions.

The *Caruncula lachrymalis* is likewiſe ſituated in the great Angle of the Eye, in the Middle betwixt the *Puncta lachrymalia*, but a little nearer the Noſe. It was commonly called the *Glandula lachrymalis*, becauſe it was ſuppoſed, tho' without Reaſon, to filtrate the *Succus lachrymalis.*

§ 3. In Brutes that have the *Membrana nictitans*, or internal Eye-lid, it is much larger than in Man, and is truly glandulous, ſerving to ſeparate a Liquor from the Blood, which is ſent by two or three Excretories to the inner Side of that Eye-lid, for moiſtening and cleaning the *Cornea.* In the Calf, theſe Excretories are large enough to admit a Hog's Briſtle, as VAXHEYEN well obſerves, who therefore ſuſpects the ſame Structure in Men. But in Man no ſuch Excretories are to be found; neither is their Texture glandulous, but of a denſe, compact, carnous Subſtance, formed by the Conjunction and Duplicature of the Membrane lining the Eye-lids internally, as MORGAGNI and others have obſerved.

Theſe Parts being commonly well enough known, I ſhall not waſte Time in explaining them further; but ſhall, in as few Words as poſſible, inquire into their Uſe.

§ 4. The *lachrymal Juice* which continually flows from the *Glandula innominata,* and which is poured out upon the Eye under the ſuperior Eye-lid, for waſhing and cleaning the *Cornea,* is, by the Motion of the Eye-lids, determined to flow along the Edge of the under Eye-lid to the *great Canthus.* The Mechaniſm by which this is affected, tho' commonly overlooked, is nevertheleſs exceeding beautiful and induſtrious, and conſiſts in the two following Particulars: 1*mo,* The Poſition of the Eye-lids is ſuch, that the Angle which they make, by their Conjunction at the external *Canthus,* is much more acute than that made at their internal *Canthus*; and therefore, when we ſhut our Eye-lids, the whole of their Edges do not touch one another at once, but begin firſt to touch at the external *Canthus*, where the Angle is ſmalleſt, and from thence they proceed ſucceſſively to touch one another thro' their whole Length, till, laſt of all, that they touch at the internal *Canthus* where the Angle is greateſt. That the Eye-lids do not ſhut all at the ſame Time, but ſucceſſively, in the Manner juſt now mentioned, is not only obvious from the above explained Diſpoſition of the Eye-lids, but may, without much Difficulty, be noticed, by obſerving their Motion in a Looking-glaſs. Whence every body muſt ſee how this ſucceſſive ſhutting of the Eye-lids muſt neceſſarily determine the Tears, which flow down the Eye, till they are ſtopt by the Edge of the under Eye-lid, to run along this Edge towards the *great Canthus;* more eſpecially that this *Canthus* is ſomewhat lower than the external one.

2do, A ſecond Thing that contributes to this End, is the Diſpoſition of the Edges of the Eye-lids themſelves, which, when ſhut by the Contraction of the orbicular Muſcles, do touch one another very cloſely externally: But internally, at their inner Edge, they at firſt do not at all touch, but leave a ſort of Furrow on the inner Edge of the under Eye-lid, along which the Tears are preſſed by the further Contraction of the orbicular Muſcle, which, by preſſing the Eye-lids together with more Force, obliterates this Furrow, firſt towards the external Angle, and thence ſucceſſively to the internal Angle, which, laſt of all, is effaced. Theſe are the Reaſons why the Tears are determined to run along the Edge of the Eye-lids to the *great Canthus*; and why any Particle of Sand, falling into the Eye, is thereby ſoon carried to that Place, as all of us have often obſerved. Hence it is, that, if any of theſe two Cauſes are wanting, the Tears are not properly directed to the *great Canthus*, but run down the Cheeks; as is frequently to be obſerved, when the under Eye-lid has loſt its Figure, or when its Edge is in any Part cut or corroded, ſo as to allow the Tears to eſcape.

From what has been ſaid, we hope all may underſtand by what Mechaniſm the lachrymal Juice, together with the Duſt and Filth waſhed off the *Cornea*, is tranſmitted to the *great Canthus*, where there is a ſmall Cavity formed for their Reception; for in this Angle is placed that carnous Tubercle called the *Caruncula lachrymalis*, which, by its Protuberancy, hinders the inner Surfaces of the Eye-lids from applying themſelves cloſely to the ſubjacent Parts; and therefore there is a ſmall void Space preſerved at the Baſis of this Caruncle, into which the Tears are collected.

§ 5. The Uſe therefore of this Caruncle, is, 1*mo*, To form and preſerve a ſmall Cavity in the *great Canthus* for the Reception of the lachrymal Juice.

2*do*, To hinder this Juice from running out upon the Face at the *great Canthus*, which it would certainly do, were it not ſtopt by this Caruncle: For the Eye-lids, when ſhut, do but ſlightly touch one another at their Conjunction in this Angle; and therefore would eaſily allow the Tears to eſcape at the angular Point where they preſs leaſt upon one another, did not this Caruncle intercept their Motion, as GALEN of old well obſerves, in theſe Words: *Ne igitur per angulos excrementum effluat, neve aſſidue lachrymemus, prædictis meatibus corpora hæc carnoſa fuerunt appoſita, quæ prohiberent quidem, ne oculorum excrementa per angulos vacuarentur, ad proprios autem meatus impellerent.* Hence it is, that when this Caruncle is conſumed, either by Suppuration, or by the Corroſion of acrid Humours, or Medicines imprudently applied, the Tears run out filthily upon the Cheeks all the Life-time.

3*tio*, A third Uſe of this Caruncle, is to keep the *Puncta lachrymalia* open, which otherwiſe would be ſtopt, by having their Orifices applied to the ſubjacent Parts; for this Caruncle, as we ſaid before, by its Protuberancy, forms a ſmall empty Space at its Baſis, into which the Tears are collected. It is into this Cavity or Space the Mouths of the *Puncta lachrymalia* gape, which muſt therefore receive the Tears contained therein, and tranſmit them to the *Saccus lachrymalis*, from which they are carried by the *Ductus naſalis* into the Cavity of the Noſe.

§ 6. There are ſome who, in examining the Poſition and Courſe of this Paſſage from the Eyes to the Noſe, have thought it ſomewhat unfavourable for the Motion of the Tears that way; and therefore, to forward their Paſſage, they have ſuppoſed, that the *Puncta lachrymalia*, by Attraction, abſorb the Tears into themſelves, in the ſame manner as Water is attracted in capillary Tubes; and as this *Apparatus*, according to them, is analagous to a capillary Syphon with unequal Legs, the Tears attracted by the Points flow in the ſame manner out of the longer Leg which inheres in the Noſtrils. But whatever be in this, the Motion of the Tears muſt alſo be promoted by the Contraction of the orbicular Muſcle, which, by leſſening the Cavity at the *great Canthus*, into which the Tears are collected, muſt preſs them forward thro' this Paſſage towards the Noſe.

Thus the *Succus lachrymalis*, together with the Filth waſhed off the *Cornea*, is conveyed to the Noſe, when in a natural Quantity; but when its Quantity is ſo great, as that all of it cannot paſs by theſe *Puncta*, as frequently happens upon any violent Paſſion of Mind, ſuch as Grief, Anger, Joy, *&c.* or when the lachrymal Gland, or its Excretories, ſuffer any Relaxation or Irritation ; or, laſtly, when this Gland is ſtrongly compreſſed by the Contraction of the orbicular Muſcle of the Eye-lids preſſing in the Globe of the Eye, when it is fretted by Smoke, Sand, or ſuch like injurious Particles ; I ſay, when from any of theſe Cauſes the lachrymal Juice is in ſuch a Quantity, as that all of it cannot enter the *Puncta lachrymalia*, then it flows down the Cheeks in form of Tears.

§ 7. From all which it is eaſy to underſtand why the Acrimony of this Humour ſometimes cauſeth Sneezing ; which we can hinder, by preſſing the Angle of the Eye, ſo as to ſtop its running. We may alſo ſee, why, upon weeping, the Noſe drops a thin clear Liquor ; for in this laſt Caſe, the lachrymal Juice flows into the Noſe, in as full a Stream as the ſmallneſs of the *Puncta lachrymalia* can allow of ; which therefore muſt fall down from the Noſe in thoſe thin clear Drops, which have eſcaped no body's Obſervation. From this alſo we may ſee how Applications made to the Eyes get into the Noſe and Mouth, as GALEN has obſerved ; and how ſome can make Smoke paſs from their Mouth to their Eyes. We may from this alſo ſee, how that famous Empyric, taken notice of by Spigelius, could purge his Patients by dropping into their Eyes a few Drops of a certain Eye-water, which never failed giving them two or three Stools, as Plempius informs us. And, laſtly, from what has been ſaid, it is eaſy to underſtand, why, in Diſeaſes of the Eyes, accompanied with hot ſharp Tears, not only the Cheeks, but alſo the Noſe and Upper-lip are ſo often galled and fretted by the ſharpneſs of this Humour, which ſometimes at laſt excoriates them, and brings on a Scabbineſs in theſe Parts.

A
TREATISE
ON THE
EYE, the Manner and *Phænomena* of VISION.

BOOK II.

Of the Globe or Body of the Eye.

CHAP. I.

Of the Situation of the Eye.

SECT. 1. HAVING, in as little Compaſs as the Subject would allow, diſpatched what I thought neceſſary to be ſaid on the external Parts of the Eye, the Order propoſed now leads me to conſider the Globe or Body of the Eye itſelf; after which, I ſhall, from the known Properties of Light, deduce the Uſe of its ſeveral Parts, and explain the Manner and various *Phænomena* of Viſion.

The Globe or Body of the Eye, is that Inſtrument or Organ of the Body, compoſed of Membranes, Humours and Veſſels, by which the viſual Species or Images of external Objects, are formed on the Bottom of the Eye, from whence they are conveyed, and repreſented to the Mind, for cauſing Viſion.

For our clearer proceeding in the Conſideration of this noble Part, and for underſtanding its beautiful Oeconomy, I ſhall conſider theſe ſix Things: 1*ſt*, Its Situation in the Body; 2*dly*, Its Connection with the Orbits in which it is placed; 3*dly*, Its Form; 4*thly*, Its Number; 5*thly*, Its Motions; 6*thly*, and *laſtly*, Its Fabric and Compoſition.

§ 2. As to the *Firſt*; The Situation of the Eye. In Man, as well as in all other Creatures I know, the Eyes are ſituate in the Head. PLINY indeed, in his *Natural Hiſtory*, makes mention of the *Blemmyans*, a People in *Æthiopia*, having no Head, but having their Eyes and Mouths in their Breaſts; he alſo makes mention of the *Tragloditians*, a People beyond *Ægypt*, on the Weſt-ſide of the Gulf of *Arabia*, who dwelt in Holes and Caves, and who having no Neck, had their Eyes in their Shoulders: Which Fables I take notice of, more for the Reader's Diverſion, than for any Truth that is in them.

The Reaſons why the Eyes are placed in the Head, are: 1*ſt*, That they may be nearer the Brain, and conſequently may, with greater facility, convey the Images of external Objects to the common *Senſorium*. Had they been placed at any conſiderable Diſtance from the Brain, the ſmall Agitation excited in the optic Nerves, by the Action of ſuch ſubtile Particles as thoſe of the Rays of Light, might have been ſtiffied, or in a great meaſure diminiſhed, before it could reach the common Senſory. This therefore may be one Reaſon why the Organs of all our Senſes, except that of Feeling, are placed in the Head, as near the Brain as poſſible.

There was indeed an abſolute Neceſſity that the Senſe of Feeling ſhould have been diffuſed thro' all our Body, that every Part might be apprized of Things ſafe or prejudicial to it, from the Pleaſure or Pain they afford; for had Nature confined this Senſe to any one particular Part of the Body, then all the reſt would have been expoſed to the Danger of being burnt, bruiſed, torn, or otherwiſe hurt, without our Knowledge, upon a thouſand Occaſions; which Inconveniencies we are now warned to avoid by this Senſe of Feeling; which is therefore wiſely diſperſed throughout every part of our Bodies: But, becauſe of its Diſtance from the Brain, as well as for other Reaſons not needful to be taken notice of at preſent, this Senſe does not affect our *Senſorium*, or impreſs our Mind with any Ideas, but when the Nerves are more violently agitated by the Action of Bodies, than what happens in the other Organs of Senſe.

By our Senſe of Feeling, we eaſily perceive a Table, a Book, a Pen, or ſuch like groſs material Objects, becauſe they act upon our Nerves with Force and Vigour: But we do not thereby at all perceive the Rays of Light, the Particles of odoriferous Bodies, or the Motion of the Air in Muſic or other Sounds; becauſe, amongſt other Reaſons, the Impreſſion they make upon the Nerves of that Senſe and the Agitation thereby excited, is ſo weak, that it is altogether ſtiffled and loſt before it can reach the *Senſorium*. But all theſe Impreſſions, received by the proper Organs of Sight, Smelling, and Hearing, are eaſily conveyed to the Brain, becauſe of their Proximity to it; which therefore may be one Reaſon why the Eyes, as well as the other Organs of Senſe that are affected by the Impreſſions of a ſubtile *Medium*, are placed in the Head near the Brain.

§ 3. *Secondly*, Another Reaſon why the Eyes are placed in the Head, is, becauſe it is the moſt erect and eminent Part of the Body. Had they been in the Foot, or any Part below the Head, our Sight would have been very much limited and confined: But by this Situation we can caſt our Eyes upwards, downwards, and round about us at pleaſure, and entertain ourſelves with a glorious Hemiſphere of the Heavens, and an ample Horizon on Earth, at the ſame time. In the Hands, they might indeed (in Man) be rendered more eminent than in the Head, and be turned about here and there at pleaſure; but then they would be expoſed to many Injuries in thoſe active Parts, and the Hands themſelves would have been rendered leſs active and uſeful.

If any ſhould be ſo curious as to deſire to know how far a Man's Proſpect reacheth by means of the Height of his Eye, ſuppoſing the Earth was an uninterrupted Globe; the Method is a common Caſe of Right-angled plain Triangles, where the Hypothenuſe and one of the Sides are given, and the other is ſought.

Thus ſuppoſe (Plate I. Fig. 3.) A H B the Surface of a great Circle of the terraqueous Globe, C the Centre, E the Height of the Eye. Draw the Line CE, and from the Point E draw the Tangent E H, and join C and H. It is plain, that when the Eye is placed at E, its Proſpect will extend to H, whoſe Diſtance from E is eaſily found from the 47th Prop. of the firſt Book of *Euclid*; which demonſtrates, that in Right-angled Triangles, the Square of the

Hypothenuſe is equal to the Sum of the Squares of the other two Sides. And therefore, in the Right-angled Triangle CHE, the Side EH, or Extent of a Man's Sight, is found, by ſubtracting the Square of CH from the Square of the Hypothenuſe CE; the Remainder gives the Square of EH, whoſe Square-root being extracted, gives the Line EH, or Extent of a Man's Proſpect.

The Line CH, being the Semidiameter of the Earth, is known from thoſe accurate Obſervations of a Degree made by Mr NORMAND in *England, and* Meſſ. PICART and CASSINI in *France*, to be nearly 3983,86 Engliſh Miles, or 7011594 Yards: The Line CE is the ſame with the Addition of two Yards for the Height of the Eye above the Surface of the Earth, or 7011596 Yards, and therefore is alſo known: from which, according to the above Method, the Line EH is found to be equal to three Miles, which is the Diſtance the Eye can reach at the Height of ſix Feet.

§ 4. This would be the Diſtance on a perfect Globe, did the viſual Rays come to the Eye in a ſtreight Line; but by Means of the Refractions of the Atmoſphere, diſtant Objects on the Horizon always appear higher than really they are, and therefore may be ſeen at a greater Diſtance. But this will vary according to the various Conſtitutions of the Air; an

Object which at Break of Day has appeared in the Level, and ſometimes above it, has afterwards, when the Sun was up, appeared below it; and, on the contrary, after the Setting of the Sun, Objects far diſtant have appeared to be raiſed ſo ſenſibly, that in leſs than half an Hour their apparent Height has been augmented more than three Minutes, by reaſon of the Condenſation and Deſcent of the Vapours, which increaſe the Refraction. On the Sea, this Refraction is yet greater than upon Land, by which we are enabled to diſcover Objects at a much greater Diſtance than the Convexity of the Sea ought to permit, and even at a greater Diſtance than upon Land; which is of great Uſe to diſcover the Land, Rocks, *&c.* which otherwiſe might not be obſerved till it was too late; and thus, by the Refraction of the Atmoſphere, the viſible Horizon is enlarged, which is all one as if the terraqueous Globe was much larger than really it is.

§ 5. *Thirdly*, and *laſtly*, Another Reaſon why the Eyes are ſituate in the Head is, That it is the moſt convenient Place for their Defence and Security, being compoſed of hard Bones, wherein are formed two large ſtrong Sinuſes or Sockets, commonly called Orbits, for the convenient lodging thoſe tender Organs, and ſecuring them againſt external Injuries.

ries. Hence it is, that in thoſe Creatures whoſe Head, like their Eyes, and the reſt of their Body, is ſoft, and without the Guard of Bones, Nature hath provided for this neceſſary and tender Organ a wonderful kind of Guard, by endowing the Creature with a Power of withdrawing its Eyes into its Head, and lodging them in the ſame Safety with its Body. We have a beautiful Example of this in Snails, whoſe Eyes being contained in their four Horns, like ſo many atramentous Spots, fitted to the Ends of their Horns, or rather to the Ends of thoſe black Filaments or optic Nerves which are ſheathed in their Horns, (as Dr. POWER wordeth it (*Obſ.* 31. *Pag.* 36.) they can protrude or retract them at Pleaſure, as they have occaſion to uſe or guard their Eyes.

§ 6. If it ſhould be aſked, Why our Eyes are placed in the Fore-part of our Head, rather than on the Top of our Head, or behind? It is eaſy to anſwer, That, had they been in the Top of our Head, we could then have ſeen the Heavens indeed, but the greateſt Part of viſible Objects here on the Earth would have been hid from us. And with regard to Brutes, their Nature is altogether repugnant to ſuch a Situation; as they gather their Food from the Ground, which their Sight in that Caſe could not have reached. In like manner, had our Eyes been placed behind, they could not have aſſiſted us to walk forwards towards any Object, or to avoid the Dangers in our Way. It is therefore with good Reaſon that the Eyes of all Animals are ſituated in the Fore-part or Side-parts of their Head, according to the particular Occaſions of particular Animals. In Man, and ſome other Creatures, they are placed towards the Fore-part, to look directly forward chiefly; but withal they are ſo ordered, as to take in nearly the whole Hemiſphere before them; which is evidently the beſt Situation that could poſſibly have been given them, for enabling us to guide and direct our Steps, to avoid the Precipices and Dangers in our Way, and to ſee and examine the Objects before us, towards which we are moved, and towards which our Hands are made to extend.

In Birds, and ſome other Creatures, the Eyes are ſo ſeated, as to take in nearly a whole Sphere, that they may the better ſeek their Food, and eſcape Dangers. And in ſome Creatures they are ſeated ſo, as to ſee beſt behind them, or on each Side; whereby they are enabled to ſee their Enemy that purſues them that Way, and ſo make their Eſcape. Thus, in Hares and Conneys, their Eyes are very protuberant, and placed ſo much towards the Sides of their Head, that their two Eyes take in nearly a whole Sphere; whereas in Dogs, that purſue them, the Eyes are ſet more forward in the Head, to look that Way, more than backward.

CHAP. II.

Of the Connection of the Eyes.

SECT. I. OUR Eyes being placed in the Orbits, are kept in that Situation by their Muſcles, the optic Nerves, and the Fat lining the Orbits; to all which our Eyes are attached. But that which chiefly connects the Eyes to their Orbits, is a Membrane called *Conjunctiva* or *Adnata*. This therefore I ſhall here only conſider, omitting the others, which being leſs concerned in this Matter, fall more naturally to be conſidered in another Place.

§ 2. The *Conjunctiva* takes its Origin from the *Perioſteum*, all round the Edge of the Orbit, and from thence is extended over the whole Fore-part of the Globe, till its Termination in the Edge of the *Sclerotica* adjoining to the *Cornea*, where of conſequence it forms a large Hole for the tranſparent *Cornea*, thro' which the *Iris* and Pupil are ſeen. From its Situation, it is called *Adnata*, and from its Office, *Conjunctiva*.

§ 3. This Membrane is nothing but a Continuation of the *Perioſteum* lining the Orbits internally. It is covered externally with another Membrane; for, as is known to Anatomiſts, the internal Membrane of the Eye-lids at the Edge of the Orbit, folds back again over the outward Face of the Eye above the *Conjunctiva*, to which it adheres, and with which it terminates at the Edge of the *Sclerotica*, where the *Sclerotica* joins the *Cornea*.

Theſe two Membranes, becauſe of their cloſs Union, appear to be only one, and are generally deſcribed as ſuch, under the Name of *Membrana albuginea*, ſo called, becauſe they form the White of the Eye; tho' in fact they are diſtinct Membranes, the one a Continuation of the *Perioſteum*, lining the Orbits internally, and the other of the inner Membrane of the Eye-lids, which, notwithſtanding their ſtrict Union, may eaſily be ſeparated, and have their diſtinct Origins clearly demonſtrated.

§ 4. If it ſhould here be aſked, For what Ends theſe Tunicles are made always of a ſhining white Colour? It may be ſufficient to anſwer: *firſt*, That ſuch a Colour adds greatly to the Beauty of the Eye and Countenance; and, *ſecondly*, That, by ſurrounding the Pupil and *Iris*, this Colour, by its Oppoſition, renders them more bright and conſpicuous, by which Means we are better enabled to judge of the

Direction of the Eyes, and when any body looks at us; which in many caſes is of conſiderable Uſe to us, and which could not be ſo eaſily known, were our Eyes all over of the ſame Colour; as has been well obſerved by that learned Mathematician, and great Philoſopher, JOANNES KEPLERUS. Hence, in Dogs, and ſome other Creatures that have the Fore-part of their Eyes moſtly of the ſame Colour, it is extremely difficult for us to judge towards what Object their Eyes are turned, eſpecially if they be at any conſiderable Diſtance from us.

§ 5. Theſe Membranes, eſpecially the external one, coming from the Eye-lids, are ſo full of Blood-veſſels, and ſo laxly extended over the Eye, that in violent *Ophthalmia's*, the White of the Eye is ſometimes ſwelled ſo exceſſively, as to cover all the *Cornea*; which I here take Notice of, becauſe it is ready not only to ſurpriſe, but to impoſe on the unwary or unexperienced Oculiſt, as if it were an incurable Excreſcence of the *Cornea* itſelf; whereas the Danger of ſuch *Ophthalmia's* lies not ſo much in the ſwelling of this Membrane, as in ſome of the other Parts of the Eye, which, when affected at the ſame time, makes the Diſeaſe more or leſs dangerous, according as this or the other Part is more or leſs affected; all which may be known by the Symptoms,

ptoms, and is of the greateſt Uſe to be obſerved in Practice; as might eaſily be ſhown in a Variety of Caſes, were this a proper Place for ſuch Inquiries.

§ 6. Beſides theſe two Membranes, the Fore-part of the Globe is covered all over externally with a very thin tranſparent *Aponeuroſe* or *Surpeau*, which not only covers the Membrane which it has from the Eye-lids, but is alſo extended beyond it over the *Cornea* itſelf. The *Phlyctenæ*, which are ſmall tranſparent Veſſicles full of clear Water, and which are frequently obſerved upon the Surface of the *Cornea* itſelf, as well as upon the White of the Eye, and even ſometimes have their Centre in ſome Part of that Circle of the *Cornea* where it joins the *Sclerotis*, and by that Means occupy at the ſame time, both a Part of the White of the Eye, and a Part of the *Cornea*, are, amongſt other Things that might be advanced, a convincing Proof of the Exiſtence of this Cuticle or *Surpeau*, and of its Extention over the whole *Cornea*.

This Cuticle ſeems to me to be a Production of the *Epidermis*, or Scarf-ſkin, which at the Edge of the Eye-lids folds inwards, ſo as to cover the Inſide of the Eye-lids, and at the Edge of the Orbit folds back again over the whole outward Face of the Eye. The *Exuviæ* of Serpents, which are obſerved to be one continued Membrane that covered their whole Bodies, their Eyes, as well as the reſt of their Body, is, amongſt other Things that might be mentioned, a pretty ſtrong Proof, not any of the Extention of this Cuticle over the whole *Cornea*, but alſo of its being a Production of the *Epidermis*.

§ 7. There is yet another Tunicle covering the Fore-part of the Globe, and connecting it to the Orbit, which had eſcaped the Obſervation of moſt Anatomiſts, till COLUMBUS took Notice of it, and which therefore, it is probable, had been conſidered as a Part or Pellicle of the *Conjunctiva*, from which nevertheleſs it is quite diſtinct.

This Tunicle ariſes from the Tendons of the four ſtreight Muſcles of the Eye, and expanding itſelf over the Fore-part of the Globe, betwixt it and the *Conjunctiva*, to both which it adheres, it terminates at the Edge of the *Sclerotis*, where it forms the *Cornea*. COLUMBUS aſſumes the Honour of being the firſt Diſcoverer of this Tunicle, to which he has given no Name. Hence it is frequently called *Tunica Innominata Columbi*, tho' unjuſtly, becauſe it was known to GALEN, as appears from the 2d and 8th Chapters of his tenth Book *De uſu partium*. Others therefore, with better Reaſon, call it *Tunica Tendinea*, becauſe formed of the Tendons of the four ſtreight

Muſcles, of which it is an Extenſion or *Aponeuroſe*. FABRICIUS *ab Aquapendente* is of opinion, that the *Conjunctiva* has its ſhining Whiteneſs from this tendinous Coat. But in this he has been refuted by PLEMPIUS, who having ſeparated theſe Coats, found the *Conjunctiva* of the ſame ſhining white Colour it had before Separation, and which being opake, can receive no Change of Colour from this tendinous Coat lying behind it.

It is by theſe Membranes chiefly that our Eyes are connected to their Orbits; and being ſoft, flexible and yielding, they do it in ſuch a manner as not in the leaſt to impede their neceſſary Motions.

CHAP. III.

Of the Form of the Eye.

SECT. I. IN all Animals that I know, the Eye is of a round globular Form. In Man and Quadrupeds it is almoſt an exact Sphere; but in Birds and Fiſhes it is flat and depreſſed, both in its fore and back Part, and is rather ſpheroidal than ſpherical.

§ 2. This round Figure is of all others the moſt commodious for the Motion of this Organ; for all its Parts being nearly at the ſame Diſtance from its Centre, none of them can ſtrike againſt any Part of the Socket, or of the Fat which lines it, when the Eyes are moved; and therefore, by this Figure, our Eyes are well prepared to move every Way the Situation of Objects can require. And, *Secondly*, By this Figure, our Eyes are beſt fitted to contain the Humours within, and to receive and refract the Rays of Light coming from Objects without, ſo as to form a Picture of them on the Bottom of our Eyes, for cauſing Viſion. This ſcarce needs any Proof or Illuſtration; it being obvious, that, were it not for the Convexity of the *Cornea*, the Rays could not be made to converge ſo as to paſs the Pupil, and form this Picture upon the *Retina;* as will appear more fully from what is to follow concerning the Manner of Viſion and the Uſe of the ſeveral Parts of the Eye; which I ſhall not now anticipate, but ſhall only notice what the famous FRYAR BACON has ſaid on this Head. His Words are: " *Nam ſi eſſet planæ figuræ, ſpecies rei majoris oculo non poſſet cadere perpendiculariter ſuper eum. Cum ergo oculus videt magna corpora, ut fere quartam Cœli uno aſpectu, manifeſtum eſt, quod non poteſt eſſe planæ figuræ, nec alicujus niſi ſphæricæ, quoniam*

quoniam ſuper ſphæram parvam poſſunt cadere perpendiculares infinitæ, quæ a magno corpore veniunt, et tendunt in centrum ſphæræ: Et ſic magnum corpus poteſt ab oculo parvo videri. For the Demonſtration of this, he hath given us a Figure in his Perſpectives, which I ſhall not now conſider. But,

Thirdly, To theſe Reaſons for the Sphericity of the Eye, I ſhall add another, which is ſeldom attended to by Authors, *viz.* That the Diſtance of the *Retina* or immediate Organ of Sight from the cryſtalline Humour, may be every where ſuch as is neceſſary for receiving the Rays of Light which come from all the Points of the Object in their *Focus*. Every body knows, that there can be no diſtinct Viſion, unleſs all the Rays which enter the Eye from the ſeveral Points of the Object be united by the Reflection of the Humours in ſo many diſtinct Points in the Bottom of the Eye; and therefore, was the Eye a Cube, or of any multangular Form, ſome Parts of the *Retina* would be too far off, and ſome too nigh, theſe refracting Humours, and ſo could not but receive the ſeveral Pencils of Rays, ſome before they meet in the *Focus*, and others after they meet, which would render the Images of Objects, and conſequently Viſion, very confuſed and indiſtinct: But, by means of the ſpherical

Figure of this little Organ, the Humours are not only commodiouſly laid together for performing their Office of Refraction, but all the Parts of the *Retina* are placed at a due focal Diſtance behind the *Chryſtalline*; which therefore muſt regularly receive the Images of Objects from without, and by tranſmitting them to the *Senſorium*, prevent that confuſed and indiſtinct Viſion, which would neceſſarily happen, were the Eye of any other Figure.

But for a full Demonſtration of this Point, I muſt refer to Opticians, who have demonſtrated, 1*mo*, That if an Arch of a Circle deſcribed upon the Center of the Eye be looked at for an Object, its Image behind the *Chryſtalline* will be a ſimilar concentric Arch, whoſe Length will be to the Length of the Object in the *Ratio* of their Diſtances from the common Centre. 2*do*, If a ſtreight Line cutting the Axis of Viſion at right Angles be looked at for an Object, its Image behind the *Chryſtalline* will be the Arch of an *Ellipſis*, whoſe Axis coincides with the Axis of the Eye. From theſe Propoſitions, which I muſt not ſtay to demonſtrate, it is obvious, that when the viſual Object is convex, its Image behind the *Chryſtalline* will be an Arch whoſe Curvature muſt be greater than either that of a Circle or an *Ellipſis*. From all which, it is extremely plain, that Objects of all Figures are ſeen the more diſtinctly that the Eye are ſpherical, and conſequently that this Figure is the very beſt that could have been given to our Eyes.

CHAP. IV.

Of the Number of the Eyes.

SECT. I. ANOTHER thing remarkable in this noble Organ, is its Number, which is never leſs than two in any Inſtance that I know of, and in ſome it is more.

PLINY indeed, in his *Natural Hiſtory*, (Book 11. Chap. 37.) tells us of a Sort of Heron with but one Eye: *Inter aves* (ſays he) *ardeolarum genere, quos Leucos vocant, altero oculo carere tradunt.* Theſe are PLINY's own Words; but not having ſeen it himſelf, he reports it only from Hear-ſay, and therefore the Account is thought fabulous; as likewiſe what he tells us in the 30th Chapter of his 3d Book, concerning the King of the *Nigræ* that hath but one Eye, and that in his Forehead.

§ 2.

§ 2. The Advantages of having two Eyes are, by the generality of Anatomiſts, confined to Two.

1*ſt*, That the Sight may be rendered more ſtrong and perfect; which indeed is a very good Reaſon in Man, Dogs, Sheep, Oxen, and ſuch other Creatures as look the ſame Way with both Eyes; for ſince each Eye apart impreſſes the Mind with an Idea of the ſame Object, the Impreſſion muſt be ſtronger and more luminous, when both Eyes concur, than when only one; and conſequently the Mind will receive a more ſtrong, lively and perfect Idea of the Object in View.

§ 3. To be aſſured that Objects appear brighter and ſtronger to both Eyes than to one alone, and to find to what Degree this Exceſs of Brightneſs amounts, the learned Doctor JURIN has made ſeveral curious Experiments, which I ſhall here relate, and that the rather, that it may be imagined that an Object ſeen with both Eyes ſhould appear twice as bright and luminous, as when ſeen only by one; which nevertheleſs is contrary to Experience. The Experiments are as follows:

I laid a Slip of clean white Paper directly before me upon a Table, and applying the Side of a Book cloſs to my right Temple, ſo as the Book advanced conſiderably more forward than my Face, I held it in ſuch manner as to hide from my Right-eye that Half of the Paper, which lay to my Right-hand, while the left Half of the Paper was ſeen by both Eyes without any Impediment.

Then looking at the Paper with both Eyes, I obſerved it to be divided from Top to Bottom by a dark Line, and the Half of the Paper which lay to the Right-hand of this Line, to appear conſiderably darker than the Half which lay to the Left-hand.

In looking at other Objects in the ſame manner, as at the Wainſcot or the Cieling, I conſtantly found that Part which was ſeen by one Eye only to appear manifeſtly darker than that which was ſeen by both Eyes: And when the Book was applied to my left Temple, inſtead of the right, the ſame Difference was obſerved; which ſhewed my two Eyes to be of equal Goodneſs.

When I looked in this Manner upon a Page of a Book divided into two Columns, I found the Column that was ſeen with both Eyes to be much plainer and more legible than that which was ſeen with one only; and this Difference was more conſpicuous, when, in making the Experiment by Candle-light, the Book was at ſuch a Diſtance from the Candles, as that there was ſcarce Light enough to read with both Eyes: For then the Column which was ſeen with one Eye only, was not at all legible; but I could read the other, tho' with ſome Difficulty.

Being now fully ſatisfied, that an Object ſeen with both Eyes appeared brighter and ſtronger than when viewed with one; I next endeavoured to find to what Degree this Exceſs of Brightneſs amounted; particularly whether there was as much Difference in the Brightneſs of an Object when ſeen with one Eye and with both, as when illuminated by one Candle and by two.

To this End, I ſet upon a Table two Candles of equal Height, and burning to Appearance with equal Light, at about a Foot Diſtance beyond a Slip of white Paper lying before me, and about four Inches from one another, ſo as that the Diſtance between the Candles was parallel to the Slip of Paper.

Then I ſet a Book upon one End between the Right-hand Candle and the Paper, ſo as to caſt a Shade from that Candle upon the Right-hand Half of the Paper: Thus the left Half of the Paper was illuminate by two Candles, and the right by one only; conſequently the left Half was twice as luminous as the right; and the Boundary between thoſe two Halfs was pretty well defined by the Edge of the Shade.

I then took another Book, and applied it to my left Temple in ſuch a Manner as to hide the left and brighter Half of the Paper from my Left-eye; ſo that the left Half was ſeen by my Right-eye only, while the other Half was ſeen by both Eyes: Now I expected that the right Half of the Paper, having the Light of one Candle only thrown upon it, but being ſeen with both Eyes, would appear as luminous as the left Half, which had twice as much Light caſt upon it, but was ſeen by one Eye only. In which I found myſelf miſtaken; for the left Half appeared much whiter and brighter than the right: Conſequently an Object ſeen with both Eyes is nothing near twice as luminous, as when ſeen with one only.

Being deſirous to know the Quantity of this Exceſs of Brightneſs more exactly, I fixed a Slip of white Paper flat againſt the Wainſcot by the help of Pins, and, at a Yard Diſtance, I ſet a Candle ſo as that the Flame was about the ſame Height with the Paper, and nearly oppoſite to the Middle of it, but rather inclining to the right Side. At two Yards Diſtance from the Paper, I placed another Candle, with its Flame at the ſame Height, and oppoſite to the Middle of the

left

left Half of the Paper. Then I ſet up a Book ſo as to cut off the Light of this ſecond Candle from the left Half of the Paper; which Half therefore being illuminated by one Candle only, appeared conſiderably darker than the right Half of the Paper on which both Candles ſhone without Interruption.

The Difference in the Brightneſs of the two Halves of the Paper is eaſily eſtimated, by conſidering that the ſecond Candle, being at twice the Diſtance, muſt throw upon the right Half of the Paper juſt a Quarter of the Light that was caſt upon the ſame Half by the nearer Candle; and conſequently that the luminouſneſs of the right Half of the Paper was to that of the left Half, as five to four.

Things being thus diſpoſed, and the Candles burning with equal Brightneſs, I applied a Book to my right Temple, ſo as to hide the right Half of the Paper from the Right-eye; then looking at the Paper with both Eyes, the right Half of it, which had five Degrees of Light, and was ſeen by the Left-eye only, appeared manifeſtly whiter than the left Half, which had four Degrees of Light, and was ſeen by both Eyes. Conſequently, an Object ſeen with both Eyes is not a Quarter Part more luminous than when ſeen with one only.

After the ſame Manner, by ſetting the ſecond Candle at three Yards Diſtance from the Paper, I found that the right Half of the Paper, which then had ten Portions of Light thrown upon it, and was ſeen by one Eye, appeared ſomething whiter than the left Half, which was illuminated by nine Portions of Light, and was ſeen by both Eyes.

When I removed the ſame Candle one foot further, ſo that the Diſtances of the two Candles from the Paper were reſpectively as 3 and 10, and conſequently the Quantities of Light they threw upon the right Half of the Paper were as 100 and 9 reſpectively, *i. e.* nearly as 11 to 1; the right Half of the Paper ſeen with one Eye only, ſeemed ſtill a little whiter than the left Half ſeen with both.

When the ſecond Candle was ſet at the Diſtance of four Yards from the Paper, the right Half of the Paper ſeen with one Eye, appeared a little darker than the left Half ſeen with both Eyes.

Hence it follows, that when the ſecond Candle is about 11 Foot diſtant from the Paper, the right Half ſeen with one Eye, and the left Half ſeen with both Eyes, muſt appear of an equal Whiteneſs. Conſequently, an Object ſeen with both Eyes appears brighter than when ſeen with one only by about a 13th Part; but it would be difficult to make the Experiment exactly. So far Dr. JURIN.

§ 4. *Secondly*, A Second Advantage we reap from the Number of our Eyes, is, that when one of them is loſt or hurt, the other ſtill officiates; which is a moſt uſeful Proviſion for the Misfortune of loſing one of thoſe noble and moſt neceſſary Organs. But,

§ 5. *Thirdly*, To theſe two Advantages, Optical Writers add a *third*, that we reap from the Duplicity of our Eyes, which is no leſs conſiderable than any of the former, and conſiſts in our being thereby enabled to judge with more Certainty of the Diſtance of Objects. I ſhall afterwards have occaſion to explain ſix Means which concur for our judging of the Diſtance of Objects, of all which the moſt univerſal, and frequently the moſt ſure, is the Angle which the Optic Axes make at that Point of the Object to which our Eyes are directed: When this Angle is very great, we ſee the Object very near; and, on the contrary, when it is very ſmall, we ſee it at a great Diſtance; and the Change which is made in the Situation of our Eyes, according to the Change of this Angle, is a Mean our Mind makes uſe of for to judge of the Diſtance and Proximity of Objects: For our two Eyes are like two different Stations in Longimetry, by the Aſſiſtance of which Diſtances are taken; whence it follows, that Creatures that look differently with their Eyes, as Fiſhes, Fowls, the Hare, Chamelion, *&c.* cannot judge of the Diſtance of Objects from this Angle, and therefore muſt be more liable to Miſtakes than we are; yet Nature has provided them with two Eyes, that their Sight might not be too much limited, but that they might ſee Objects equally well on both Sides, and thereby be better enabled to ſeek their Food and eſcape Dangers. Whence alſo it follows, that thoſe who are blind of one Eye, muſt be liable to Miſtakes in all Actions that require that the Diſtance be exactly diſtinguiſhed, as in pouring Liquor into a Glaſs, ſnuffing a Candle, threading a Needle, *&c.* of which that great Improver of natural Knowledge, the famous Mr. BOYLE, has given us ſeveral Inſtances in his Obſervations upon vitiated Sight. He has indeed obſerved, that this Aptneſs to misjudge of Diſtances and Situation gradually diminiſhes; the Reaſon of which muſt be, that by Uſe and Cuſtom they gradually learn to make a better Uſe of the other Means for judging of Diſtances. But it is impoſſible they can ever come to judge as well of them with one Eye, as they did with both.

§ 6. As in all Animals the Number of their Eyes is never leſs than two, ſo in ſome

Creatures it is more; and this always happens when Nature hath denied any Motion either to the Head or the Eyes; which is a very wonderful Proviſion ſhe hath ~~made~~ for the Immobility of theſe Parts. We have a beautiful Inſtance of this in Spiders, who having no Neck, cannot move their Head, but have this Defect ſupplied by the Number of their Eyes, which in ſome are four, in ſome ſix, and in ſome eight, by which they can ſee every Way, and catch their Prey *per ſaltum*, without any Motion of their Head, which Motion would have ſcarred away the timorous Fly on which they Prey.

Another Inſtance of this Kind may be found in the immoveable Eyes of Flies, Waſps, *&c.* which being a common Entertainment with the Microſcope, every body knows that their *Cornea*, is a curious Piece of Lattice-work, in which this is remarkable, that every *Foramen* or Pupil is of a lenticular Nature; ſo that we ſee Objects thro' them topſey turvey, as thro' ſo many convex Glaſſes. This lenticular Power of the *Cornea* ſupplies, as I imagine, the Place of the Cryſtalline, which ſeems to be wanting in thoſe Creatures; and it is probable, that every *Lens* of the *Cornea* hath a diſtinct Branch of the optic Nerve miniſtring to it, and rendering it as ſo many diſtinct Eyes, whereby thoſe Creatures are enabled to ſee very accurately every Way without any Interval of Time, or Trouble to move the Eye towards Objects: So that, as moſt Animals are binocular, and Spiders for the moſt Part octonocular, ſo Flies, *&c.* are multocular, having in effect as many Eyes as there are Perforations in their *Cornea*; by which Means, as other Creatures are obliged to turn their Eyes to Objects, theſe have ſome or other of their Eyes ready placed towards Objects nearly all round them. Thus particularly it is in the Dragon-fly (*Libella*) the greateſt Part of whoſe Head is poſſeſſed by its Eyes, which is of excellent Uſe to that predacious Inſect, for the ready ſeeing and darting at ſmall Flies all round it, on which it preys. And thus provident Nature has, with great Induſtry and Art, provided for the Immobility of the Head and Eyes.

CHAP. V.

Of the Motions of the Eye.

SECT. I. THE Motions of the Eye are either *external* or *internal.* I call *external* theſe Motions performed by its four ſtreight and two oblique Muſcles, whereby the whole Globe of the Eye changes its Situation or Direction. And by its *internal Motions*, I underſtand thoſe Motions which only happen to ſome of its internal Parts, ſuch as the *Cryſtalline* and *Iris*, or to the whole Eye, when it changes its ſpherical Figure, and becomes oblong or flat.

The *external Motions* fall to be explained here; but the internal ones will fall more naturally to be explained afterwards, in treating of the Manner of Viſion, and the Uſe of the ſeveral Parts of the Eye.

The ſpherical Figure of our Eyes, and their looſe Connection to the Edge of the Orbit by the *Tunica Conjunctiva*, which is ſoft, flexible and yeilding, does excellently diſpoſe them to be moved this or the other Way, according to the Situation of the Object we would view; and beſides there is a great deal of Fat placed all round the Globe, betwixt it and the Orbit, which lubricates and ſoftens the Eye, and renders its Motions more eaſy.

§ 2. Now the *external Motions* of the Eye, are, as we before hinted, performed by means of ſix Muſcles, whereof four are ſtreight, and two oblique. GABRIEL FALLOPIUS (in his *Obſervationes Anatomicæ*) is among the firſt that has given us a genuine Deſcription of the Mind the Idea of Sound. For, were this true, then to theſe juſt now named Animals, all Objects would become inviſible, to which their Eyes are directly turned, becauſe the *Choroides* is wanting in that Place where their Image falls; which being contrary to Experience, it remains that ſome other Cauſe be aſſigned for that Defect of our Sight, than the Want of the *Choroides*. But to return.

§ 7. Tho' the Action of theſe two oblique Muſcles ſeems pretty evident, yet there is ſcarce any Part of the human Body about which Anatomiſts have differed more, than in aſſigning them their proper Offices. The famous Mr. COWPER is among the firſt I know who began to reaſon juſtly about them. But it would take up too much Time to enumerate and confute the ſeveral Opinions of different Authors; and therefore I ſhall content myſelf, after what has been already ſaid of each Muſcle acting apart, to conſider what happens, when both act at the ſame Time.

Mr. COWPER, in his *Myotomia reformata*, has well obſerved, That when any of the ſtraight Muſcles act, they will rather draw the Eye inwards, within the Orbit, than turn it either ſideways, or upwards, or downwards, were it not at the ſame time drawn outwards by ſome equal Force. Now the above deſcribed Situation of theſe oblique Muſcles, excellently qualifies them for keeping the Globe from being retracted, when any of its ſtraight Muſcles act: For by their joint Contraction they muſt pull the Eye outward from the Bottom of the Orbit, and keep it ſuſpended as upon an *Axis*, for the better receiving the Motions of the ſtreight Muſcles: And this is what we think the principal Uſe of its oblique Muſcles, when acting together, ſeeing they combine both in this, while they are Antagoniſts to one another in their other Actions.

§ 8. AQUAPENDENT (in his Treatiſe, *de Oculo*, *cap.* xi.) obſerves, That in the *Pike*, the oblique Muſcles decuſſate one another in form of a Croſs; and PERRAULT (*du Mouvement des Yeux*) tells us, That they are both in the under Part of the Eye; and that becauſe in ſuch rapacious Animals, who frequently dive in purſuit of their Prey, they have occaſion more than others to turn their Eyes downwards. But this we chiefly take notice of, becauſe it may afterwards be of ſome Uſe for determining how the Eye changes its Conformation, and adapts itſelf to the different Diſtances of Objects, which ſome have aſcribed to the Action of thoſe Muſcles.

§ 9. COWPER (in his *Myotomia reformata*) quotes MULLINETE, for deſcribing a ſeventh Muſcle, which he calls the fifth right Muſcle, whoſe Office he confines to the Motion of the *Trochlea*. But, upon Examination, no ſuch Muſcle is to be found in the human Eye; and it is poſſible that MULLINETE might have been led into this Miſtake, by that Part of the *Orbicularis Palpebrarum*, which adheres to the *Trochlea*, or rather by what he might have obſerved in Dogs, who have a ſmall Muſcle ariſing near the Origin of the *Obliquus major*, and inſerting itſelf by a very ſlender Tendon into the *Trochlea*, to whoſe Motions it is ſubſervient, as DOUGLAS obſerves (*Myographia comparata*, *cap.* vi.)

§ 10. Beſides theſe Muſcles already deſcribed, Quadrupeds are provided with another, commonly called *Suſpenſorius*, from its aſſigned Uſe in ſuſpending the Eyes of ſuch Animals, as go much with their Heads hanging down towards the Ground. This Muſcle, among other Things, diſcovers that VESALIUS has not been altogether free from a Fault, which he condemns very ſeverely in GALEN, to wit, the obtruding on us the Organs of Brutes, inſtead of thoſe of the human Body, which he pretends to deſcribe; for he has both deſcribed and painted it as belonging to Man, in whom it is never found.

This Muſcle ariſes from the Circumference of the Hole in the Bottom of the Orbit thro' which the optic Nerve paſſes, and goes directly along the optic Nerve, which it embraces and ſurrounds on all Hands, and is inſerted into the back Part of the *Sclerotis*, all round the optic Nerve, betwixt it and the Termination of the ſtreight Muſcles. Fiſhes and Fowls commonly want this Muſcle, as well as Man; but Oxen, Horſe, Sheep, Hogs, and, ſo far as has been obſerved, all Quadrupeds are provided therewith, tho' in all it is not of the ſame Structure, being ſometimes compoſed of two, three or four diſtinct Muſcles, as AQUAPENDENT (*de Oculo, cap.* xi.) obſerves.

§ II. AQUAPENDENT, WILLIS and BRIGGS, with the greateſt Part of our modern Anatomiſts, are of opinion, that the only Uſe of this Muſcle, is to draw the Eye inwards, towards the Bottom of the Orbit, and to keep it ſuſpended, that when the Eye hangs down, as often happens in Quadrupeds, who gather their Food from the Ground, it may not fall too much out of the Orbit, or by its Weight ſtretch and fatigue the optic Nerve, to which it is attached. Hence they call it *Suſpenſorius*, as has been before obſerved,

ſerved. But this Action may in part be ſupplied by the ſtreight Muſcles acting together; and, beſides, a Ligament would have been ſufficient for ſuſpending the Eye; and therefore it is probable that this Muſcle has ſome other Uſe.

DR. TYSON finding this Muſcle in the *Porpeſs*, as well as in Quadrupeds, thinks its Uſe is not to ſuſpend the Bulb of the Eye, but rather by its equal Contraction of the *Sclerotis*, to which it is affixed, to render the Ball of the Eye more or leſs ſpherical, according to the different Diſtances of Objects, concerning which you may conſult his Anatomy of the *Porpeſs*, (*p.* 39.) But it is not abſolutely certain that the Figure of the Eye can be changed by the Action of this Muſcle, and that for Reaſons afterwards to be mentioned, when we come to conſider its internal Motions; and beſides, the neceſſary Change of our Eyes is well provided for by another Mechaniſm, as will alſo appear in its proper Place.

I think therefore that the Uſe of this Muſcle is not only to ſuſpend the Eye, and preſerve the optic Nerve from being too much ſtretched, but principally to aſſiſt the ſtreight Muſcles in moving the Eye, according as its different Fibres act, *e. g.* when its ſuperior Fibres act, they aſſiſt the *Attollens* in pulling the Eye up; when its internal Fibres next the Noſe act, they aſſiſt the *Adducens*; and when both together, or thoſe betwixt them act, they pull the Eye obliquely upwards towards the Noſe, and conſequently aſſiſt the *Attollens* and *Adducens* in their joint Action of moving the Eye obliquely. Comparative Anatomy makes this Opinion very probable; for, in ſeveral Animals, as we have before hinted, it is divided into ſeveral diſtinct Muſcles, whereof AQUAPENDENT has obſerved ſometimes three and ſometimes four in the Eyes of Sheep; and DOUGLAS tells us, That in a Dog it is divided ſometimes into four, and ſometimes into five, which have as many diſtinct Inſertions into the *Sclerotis*. Mr. PERRAULT's Obſervation on this Muſcle does likewiſe very much confirm this Opinion. (See his Treatiſe, *du Mouvement des Yeux.*) His words tranſlated are, " In effect we may " ſay, (ſpeaking of this Muſcle) that it con- " tributes to the Action of the ſtreight Muſ- " cles according as its Fibres act differently, " there being ſeveral Creatures, ſuch as the " Bear, Pole-cat, (*l'Ours, la Fouine*) and many " others, where this Muſcle is ſeparated into " four, having as many different Inſertions, " which being betwixt the Inſertions of the " four ſtreight Muſcles, may ſerve for the " oblique Motions of the Eye, which in

" Man are chiefly performed by the Combi-
" nation, or ſucceſſive Action of the four
" ſtreight Muſcles."

§ 12. Having examined what belongs to the Mechaniſm of the *external Motions* of our Eyes, I ſhall now beg leave to add ſome Reflexions thereon, which, I flatter myſelf, will not be altogether unacceptable to ſome Readers. And,

I. When Nature hath denied the Head or Eyes any Motion, it is to be obſerved, that ſhe has with great Care and Induſtry provided for this Defect. Dr. POWER's microſcopical Obſervations furniſh us with a beautiful Example of this: His Words are: (*Obſervat.* 8.)
" The firſt eminent Thing we found in the
" Houſe-ſpiders were their Eyes, which in ſome
" were four, in ſome ſix, and in ſome eight,
" according to the Proportion of their Bulk
" and the Longity of their Legs. Theſe Eyes
" are placed all in the Fore-front of their
" Head, (which is round and without any
" Neck) all diaphanous and tranſparent, like
" a Locket of Diamonds, or a Set of round
" Cryſtal-beads, &c. Neither wonder why
" Providence ſhould be ſo anomalous in this
" Animal more than in any other we know
" of, (*Argus*'s Head being fixed to *Arachne*'s
" Shoulders:) For, 1*ſt*, Since they wanting
" a Neck cannot move their Head, it is re-

" quiſite that Defect ſhould be ſupplied by the
" Multiplicity of Eyes. 2*dly*, Since they
" were to live by catching ſo nimble a Prey
" as a Fly is, they ought to ſee her every
" Way, and to take her *per ſaltum* (as they
" do) without any Motion of their Head
" to diſcover her; which Motion would have
" ſcarred away ſo timorous an Inſect."

It is therefore with good Reaſon that MUFFET, ſpeaking of this *Lydian* Spinſtreſs, that proud Madam, whom, for her Rivalſhip, the Fable makes *Pallas* transform into a Spider, ſays of thoſe Philoſophers that held them blind, *Sane cæcutiunt illi ſummo meridie, qui videre ipſas non vident neque intelligunt:* Which he might have ſaid with far better Reaſon, if his Eyes had been but aſſiſted with one of our common Microſcopes.

To this Purpoſe alſo belongs the ſurpriſingly beautiful and curious Mechaniſm obſervable in the immoveable Eyes of Flies, Waſps, *&c.* They nearly reſemble two protuberant Hemiſpheres, each conſiſting of a prodigious Number of other little Segments of a Sphere; all which Segments are perforated by a Hole, which may be called their *Pupil*, in which this is remarkable, that every *Foramen* or Pupil is of a lenticular Nature, ſo that we ſee Objects through them topſey-turvey, as thro' ſo many convex Glaſſes; yea, they become a ſmall Teleſcope, when there is a due focal Diſtance between them and the *Lens* of a Microſcope. LEUENHOEK's Obſervations make it probable, that every *Lens* of the *Cornea* ſupplies the place of the *cryſtalline* Humour, which ſeems to be wanting in thoſe Creatures, and that each has a diſtinct Branch of the optic Nerve anſwering to it, upon which the Images are painted; ſo that as moſt Animals are binocular, and Spiders for the moſt part octonocular, ſo Flies, *&c.* are multocular, having, in effect, as many Eyes as there are Perforations in the *Cornea.* By which Means, as other Creatures, but with two Eyes, are obliged, by the Contraction of the Muſcles above deſcribed, to turn their Eyes to Objects, theſe have ſome or other of their Pupils always ready placed towards Objects nearly all round them; whence they are ſo far from being denied any Benefit of this noble and moſt neceſſary Senſe of Sight, that they have probably more of it than other Creatures, anſwering to their Neceſſities and Way of living: And thus provident Nature has with great Induſtry and Art provided for the Immobility of the Head and Eyes.

§ 13. II. As in Man and moſt other Creatures the Eyes are ſituated in the Head, becauſe, amongſt other Reaſons, it is the moſt convenient Place for their Defence and Security, being compoſed of hard Bones, wherein are formed two large ſtrong Sinuſes or Sockets, commonly called *Orbits*, for the convenient lodging of theſe tender Organs, and ſecuring them againſt external Injuries; ſo in thoſe Creatures whoſe Head, like their Eyes and the reſt of their Body, is ſoft and without Bones, Nature hath provided for this neceſſary and tender Organ, a wonderful Kind of Guard, by endowing the Creature with a Faculty of withdrawing its Eyes into its Head, and lodging them in the ſame Safety with its Body. We have a very beautiful Example of this in Snails, whoſe Eyes are lodged in their four Horns, like atramentous Spots, one at the End of each Horn, which they can retract at Pleaſure when in any Danger. I know the learned PERRAULT (in his *Mechanique des Animaux*) ſeems to doubt of Snails having Eyes. And Dr. BROWN ranks this Conceit of the Eyes of Snails amongſt the vulgar Errors of the Multitude; but a good Microſcope would ſoon have ſhewn him his own Error. Thoſe that deſire further Satisfaction in this Particular, may conſult Dr. POWER's Obſervations, and *Liſter de Cochleis et Limacibus*.

If it ſhould be here aſked, Whence it is that Fiſhes, whoſe Eyes are not guarded and defended by Eye-lids, ſhould not alſo have a

Power of retracting their Eyes for their Defence and Security? To this I anſwer, That if we reflect on the Hardneſs of the *Cornea*, which, in all Animals that want Eye-lids, is commonly much harder than in Man, and therefore is not to be hurt by ſuch Particles as their Eyes are commonly expoſed to, we muſt ſee that ſuch a Mechaniſm would have been uſeleſs: And beſides, in ſome cruſtaceous Animals, whoſe Occaſions and Manner of living perhaps expoſe their Eyes to greater Dangers and Inconveniencies, their Eyes are well ſecured by deep Sinuſes, into which, as into a ſafe Chamber, they can retract their Eyes upon the Approach of any Danger, as has been well obſerved by FABRICIUS *ab* AQUAPENDENTE (in his Treatiſe *de Oculo*, *cap.* 14.)

§ 14. Something of a Mechaniſm ſimilar to this has alſo been thought to obtain in the Eyes of Moles, which are not blind, as ARISTOTLE, PLINY, SEVERINUS, *&c.* would perſuade us; but being provided with little black Eyes, about the Bigneſs of a ſmall Pin-head, in which not only the *aqueous*, *vitreous* and *cryſtalline* Humours, but alſo the *Ligamentum ciliare*, copped or conical *Cornea*, with the round Pupil and optic Nerve, have been manifeſtly diſcerned, they muſt neceſſarily ſerve to guide and ſecure it, when it chances to be above Ground. But becauſe this Animal lives moſt under Ground, which it digs and penetrates, it was neceſſary their Eyes ſhould be well guarded and defended againſt the many Dangers and Inconveniencies to which their Manner of living expoſes them; and this is the Reaſon why their Eyes are ſo ſmall, and that they are ſituated ſo far in the Head, and covered ſo ſtrongly with Hair, that they can be of no Service to them, unleſs they be poſſeſſed of a Power of protruding and retracting them at Pleaſure, more or leſs as they have more or leſs Occaſion to uſe or guard their Eyes, as has been obſerved by BORRICHIUS, *Epiſt. Bartholin.* 96. *cent.* iv. Mr. DERHAM's *Phyſico-theology, book* iv. *chap.* 2. &c.

I know ſome have doubted whether what we take to be Eyes in Moles are ſuch or no, and others have expreſsly denied any Humours to be therein; yet ſo accurate an Anatomiſt was GALEN for his Time, that he tells us that Moles have Eyes, the cryſtalline and vitreous Humours, encompaſſed with Tunics, agreeable to what has been ſince more diſtinctly ſeen by the Help of Microſcopes, (See GALEN, *de Uſu Partium, lib.* iv. *cap.* 6.)

§ 15. The *third* and *laſt* Reflection we ſhall make upon the Motion of our Eyes, is what regards a Problem which has very much perplexed both Phyſicians and Philoſophers, *viz.* What is the Cauſe of the uniform Motion of both Eyes?

In ſome Creatures, ſuch as Fiſhes, Birds, and among Quadrupeds, the Hare, Chamelion, *&c.* the Eyes are moved differently, the one towards one Object, and the other towards another: But in Man, Sheep, Oxen, and Dogs, the Motions are ſo uniform, that they never fail to turn both towards the ſame Place. Hence, in Operations upon the Eye, that require it to be kept immoveable for ſome Time, it is neceſſary to tie up the ſound Eye with Compreſs and Bandage, by which Means the other is eaſier kept fixed and immoveable.

§ 16. The final Cauſe of this uniform Motion of our Eyes is,

1. That the Sight might be thence rendered more ſtrong and perfect; for ſince each Eye apart impreſſes the Mind with an Idea of the ſame Object, the Impreſſion muſt be more ſtrong and lively when both Eyes concur, than when only one; and conſequently the Mind muſt receive a more ſtrong, lively and perfect Idea of the Object in View, as is agreable to Experience: And that both may concur, it is neceſſary they move uniformly; for tho' the *Retina* or immediate Organ of Viſion be expanded upon the whole Bot-

tom of the Eye as far as the *Ligamentum ciliare*, yet nothing is diſtinctly and clearly ſeen but what the Eye is directed to. Thus, in viewing any Word, ſuch as MEDICINE, if the Eye be directed to the firſt Letter M, and keep itſelf fixed thereon for obſerving it accurately, the other Letters will not then appear clear or diſtinct, becauſe the ſeveral Pencils of Rays that come therefrom, fall too obliquely on the *Cryſtalline* and other Humours of the Eye, to be accurately collected in ſo many diſtinct Points of the *Retina;* and chiefly becauſe of a certain Degree of Hardneſs, Calloſity or Inſenſibility, that obtains in all Parts of the *Retina*, excepting towards the *Axis* of the Eye, directly oppoſite to the Pupil. Hence it is, that to view any Object, and thence to receive the ſtrongeſt and moſt lively Impreſſions, it is always neceſſary we turn our Eyes directly towards it, that its Picture may fall preciſely upon this moſt delicate and ſenſible Part of the Organ, which is naturally in the *Axis* of the Eye. But if this moſt ſenſible and delicate Part happens, from a Fault in the firſt Conformation, or from any other Cauſe, not to be in the optic *Axis*, but a little off at a Side; then to ſee an Object clearly, the Eye muſt not be directed towards it, but a little to a Side, that its Picture may fall on this moſt ſenſible Part of the Organ: And this may be one Cauſe of Squinting, which, as is eaſy to ſee, muſt be altogether incureable.

Now, though it is certain that only a very ſmall part of an Object can at once be clearly and diſtinctly ſeen, namely, that whoſe Image on the *Retina* is in the *Axis* of the Eye; and that the other Parts of the Object, which have their Images painted at ſome Diſtance from this ſame *Axis*, are but faintly and obſcurely perceived, yet we are ſeldom ſenſible of this Defect; and, in viewing any large Body, we are ready to imagine that we ſee at the ſame time all its Parts equally diſtinct and clear: But this is a vulgar Error, and we are led into it from the quick and almoſt continual Motion of the Eye, whereby it is ſucceſſively directed towards all the Parts of the Object in an Inſtant of Time; for it is certain, that the Ideas of Objects, which we receive by Sight, do not preſently periſh, but are of a laſting Nature, as appears from what happens when a Coal of Fire is nimbly moved about in the Circumference of a Circle, which makes the whole Circumference appear like a Circle of Fire; becauſe the Idea of the Coal, excited in the Mind by the Rays of Light, are of a laſting

ing Nature, and continue till the Coal of Fire in going round return to its former Place; and therefore, if our Eye takes no longer Time to direct itſelf ſucceſſively to all the ſmall Parts of an Object, than what the Coal of Fire takes to go round, the Mind will diſtinctly perceive all thoſe Parts, without being ſenſible of any Defect or Inſenſibility in any Part of the *Retina*, becauſe the Idea of one Part continues, till, by the Motion of the Eye, the Image of the other Parts be ſucceſſively received upon the ſame moſt ſenſible Part of the *Retina:* And this is the Reaſon why the Globe of the Eye moves ſo quickly, and that its Muſcles have ſuch a Quantity of Nerves to perform their Motions. But I go on.

§ 17. 2. A *ſecond* Advantage we reap from the uniform Motion of our Eyes, which is yet more conſiderable than the former, conſiſts in our being thereby enabled to judge with more Certainty of the Diſtance of Objects.

There are ſix Means which concur for our judging of the Diſtance of Objects, of all which the moſt univerſal and, frequently, the moſt ſure, is the Angle which the Rays of Light make at the Object in coming thence to our Eyes: When this Angle is very great, we ſee the Object very near; and on the contrary, when it is very ſmall, we ſee it at a great Diſtance; and the Change which happens in the Situation of our Eyes, according to the Change of this Angle, is a Mean which our Mind makes uſe of for judging of the Diſtance and Proximity of Objects. To be perſuaded of the Truth of this, ſuſpend by a Thread a Ring, ſo as its Side may be towards you, and its Hole look right and left, and taking a ſmall Rod, crooked at the End, in your Hand, retire from the Ring two or three Paces, and having with one Hand covered one of your Eyes, endeavour with the other to paſs the crooked End of your Rod thro' the Ring. This appears very eaſy, and yet, upon Trial, perhaps once in a hundred times, you ſhall not ſucceed, eſpecially if you move the Rod a little quickly. This ſurpriſing Difficulty, which is found in paſſing the Rod ariſes, becauſe when one Eye is ſhut, the Angle which the Rays of Light make at the Object, in coming thence, to both Eyes, is not known; for in any Triangle, to know the Bigneſs of an Angle, it is not ſufficient to know the Length of the Baſe ſubtending that Angle, and the Magnitude of the Angle which one of its Sides makes with that Baſe, as is known to Mathematicians; but it is alſo neceſſary to know the other Angle which the other Side makes with the Baſe:

But this can never be known but in opening both Eyes, and directing them to the Object; and therefore the Mind can never make uſe of its natural Geometry, for judging of the Diſtance of the Ring, while one of the Eyes is ſhut.

§ 18. From this we may ſee the Uſe of having two Eyes placed at a certain Diſtance from one another; for by Uſe we get a Habit of judging of the Diſtance of Objects by the Direction of the *Axes*, which is ſenſible to us, becauſe it depends on the Motion of the Eye that we feel. But other Creatures, that look differently with their Eyes, as Fiſhes, Fowls, the Hare, Chamelion, *&c.* cannot judge of the Diſtance of Objects from this Angle, and therefore muſt be more liable to Miſtakes than we are; yet Nature hath provided them with two Eyes, that their Sight might not be too much limited, but that they might ſee Objects equally well on both Sides, and thereby be better enabled to ſeek their Food, and avoid Dangers: Whence it is, that in ſome Animals they are ſeated ſo as to ſee behind them, as well as on each Side. We have a very remarkable Example of this in Hares and Conies, whoſe Eyes are very protuberant, and placed ſo much towards the Sides of their Head, that their two Eyes take in nearly a whole

Sphere; whereas in Dogs that purſue them, the Eyes are ſet more foreward in the Head to look that Way more than backward.

From this alſo we may ſee, why we err ſo frequently in the Judgments we form of the Magnitude of Objects ſeen only with one Eye: For, ſince we judge not of Extenſion or Magnitude from the apparent Magnitude alone, but alſo from the apparent Diſtance, it follows, that Objects ſeen with one Eye, muſt appear ſmaller or greater, as they are imagined nearer or further off. Thus a Planet viewed with a Teleſcope, ſometimes is judged near the Eye-glaſs, and therefore appears very ſmall; while to others it appears very great, becauſe imagined a good Way beyond the Objective. The ſame Thing happens in viewing one's ſelf in a great concave Mirror not too far off; when the one Eye is ſhut, the Face does not appear very big, becauſe it is imagined at no greater Diſtance than the Surface of the Mirror; but to both Eyes it appears a great deal bigger, becauſe it is then imagined much further off, as has been obſerved by Monſ. MARIOTTE (*Traite des Coleurs.*)

It being therefore manifeſt, That the Diſpoſition of our Eyes, which always accompanies the Angle formed of the viſual Rays that flow to both Pupils, and that cut one another in that Point of the Object on which our Eyes are fixed, is one of the beſt and moſt univerſal Means we have for judging of the Diſtance of Objects; it needs be no Surpriſe, that in very great Diſtances, where the Diſtance of our Eyes bears no ſenſible Proportion to the Diſtance of the Object, it ſhould be impoſſible for us, by this, or any other Method, to judge rightly of the Diſtance, becauſe the Change that happens here to this Angle is ſo ſmall, as to be altogether inſenſible.

Every body muſt ſee, that this Angle changes conſiderably, when an Object that is only a Foot from our Eyes is tranſported to four; but if from four it be tranſported to eight, the Change is by much leſs ſenſible; if from eight to twelve, it is yet leſs; if from a thouſand to an hundred thouſand, it is ſcarce any more ſenſible, nay not tho' the Diſtance be increaſed from a thouſand to an infinite Space.

It is for this Reaſon that we are ſo often deceived in the Judgment we form of all great Diſtances, and that we ſee the Sun, Moon and Stars, as if they were involved in the Clouds, tho' it is certain they are vaſtly beyond them. And being deceived as to their Diſtance, we muſt alſo be deceived with reſpect to their Magnitude. Thus the Moon ſeems greater than the greateſt Star, tho' every body knows ſhe is vaſtly leſs. Thus the Sun and Moon appear not above a Foot or two in Diameter, if we truſt the Teſtimony of our Eyes, as did EPICURUS and LUCRETIUS, who therefore imagined them no bigger than what they appeared. Thus alſo the Sun and Moon appear greater when near the Horizon, than at a greater Height; becauſe, when nigh the Horizon, they are judged at a greater Diſtance.

§ 19. There is yet another Advantage, full as conſiderable as any of the former, that is thought to ariſe from the uniform Motion of our Eyes, and that is, the ſingle Appearance of Objects ſeen with both Eyes.

This indeed at firſt View does appear very probable; for if, in looking to any Object, you preſs one of your Eyes aſide with your Finger, and alter its Direction, every Thing will be ſeen double, which is a common Experiment wherewith Children amuſe themſelves, being delighted with the uncommon Appearance of Objects.

The ſame thing does alſo happen, when either of the Eyes is, from a Spaſm or Paralyſis of any of its Muſcles, or from any other Cauſe, reſtrained from following the Motions of the other. Thus WILLIS (in his *Anima Brutorum*, *cap.* 15.) tells us of a young

Man, long ill of the Palſy, who at laſt came to ſee all Things double, from a Spaſm in the *adducent* Muſcle of his left Eye, whereby its *Axis* was turned inwards, ſo that it could not be directed to the ſame Object with the other.

PLATERUS likewiſe (in the firſt Book of his *Obſervations*, *p.* 132.) gives us the Hiſtory of a Boy, who, after having received a Stroke on his Head, became paralytic in one of his Sides, and had his Mouth diſtorted, to whom every thing he looked at appeared double: And tho' he does not attempt to account for this Depravation of Sight, yet it is eaſy to ſee that it could proceed from nothing but a Palſy or Spaſm of one of the Muſcles of one of his Eyes, by which it was rendered incapable of following the Motion of the other.

LANGIUS alſo has a very remarkable Caſe to this purpoſe, which being a little uncommon, we muſt not omit. He tells us (in the 7th Epiſtle of his firſt Book) That, in a Wound of the Eye, it happened, thro' Neglect, to unite and adhere to the under Eye-lid; ſo that, after the Cure, that Eye was tied down, and rendered incapable of following the Motions of the other: This occaſioned every thing to appear double, till the Eye, by its frequent Motions, had at laſt ſtretched the Eye-lid, to which it was adherent, and thereby recovered its former Liberty of moving uniformly with the other.

Multitudes of Caſes of this Kind might be advanced; but I like not, without Neceſſity, to multiply Examples of the ſame Nature: Theſe are ſufficient to prove, that when our Eyes are reſtrained from moving uniformly, all Objects are ſeen double. Neither is it to be doubted, but, when the ſame *Phænomenon* occurs in drunk or maniac Perſons, it proceeds from the ſame Cauſe; the uniform Motion of our Eyes requiring an eaſy and regular Motion of the Spirits, which frequently is wanting in ſuch Caſes.

The ſame Thing does alſo happen ſometimes, ſoon before Death, when the Spirits have been worn out and exhauſted by long Sickneſs. We have a remarkable Example of this in the *Acta Hofnienſia*, publiſhed by BARTHOLIN. OLAUS BORRICHIUS there tells us, (*Vol.* 2. *p.* 198.) of a Woman that had been long ill of a Diſeaſe in her Breaſt and Spleen, to whom, two Days before her Death, all Things appeared double. He indeed attributes this *Phænomenon* to a Change in the Figure of the Humours of the Eye, and thinks that they had acquired the Form of a Polygon, or multiplying Glaſs; which is a very ſtrange out of the way Notion, and altogether improbable. The true Cauſe thereof ſeems to have ariſen from the languid irregular Motion of the animal Spirits, diſqualifying them from executing the Commands of the Will, and directing both Eyes to the ſame Object.

§ 20. For theſe, and ſuch like Reaſons, it is, that very many, both Phyſicians and Philoſophers, have been brought to believe, that, to ſee Objects ſingle, it is abſolutely neceſſary that both Eyes be directed to the ſame Object, and that this is one of the final Cauſes of their uniform Motion; and yet, when the Matter ſhall be duly examined, I am confident, little Foundation will be found for any ſuch Conſequence. But I muſt delay entering upon this Subject here, becauſe it will fall more naturally to be explained afterwards, when I come to treat of the *Phænomena* of Viſion.

§ 21. Having finiſhed what I intended to ſay concerning the final Cauſes of the uniform Motion of our Eyes, I come now to inquire into the efficient Cauſe of this Uniformity, or by what Neceſſity it happens that both Eyes are always turned the ſame Way, ſo that none of us are able at pleaſure to give them different Directions.

ARISTOTLE, of old, and after him GALEN, AVICENNA, and moſt of the Antients, do attribute this to the Union of the Optic Nerves, near the *Sella oſſis Sphenoidis*; but ſince theſe Nerves give no Branches to the Muſcles, but are wholly beſtowed upon the *Retinæ*, it follows, that they can contribute nothing towards the Motion of our Eyes, but are only for conveying to the Mind, or viſive Faculty, the Impreſſions made upon their Fund by the Rays of Light. Hence it is, that in Blindneſs from Obſtructions in thoſe Nerves, the Eyes continue to move as formerly; becauſe their Motion does not depend upon the optic Nerves, but upon their other Nerves and Muſcles. But, ſuppoſing that the optic Nerves did contribute to the Motion of our Eyes, yet their Conjunction could never occaſion this uniform Motion; becauſe, as DIEMERBROEK obſerves, (See his *Anatom. lib.* iii. *cap.* 16.) Anatomiſts have found them disjoined in ſome Subjects, who, while alive, moved their Eyes uniformly as other Men.

§ 22. It is therefore with good Reaſon that our Moderns have rejected this Hypotheſis as falſe and groundleſs; but neither have they themſelves ſucceeded better, when they tell us, That this happens becauſe the Nerves beſtowed upon the Muſcles of our Eyes, called *Oculorum Motorii*, are united at their Origin in the Brain. Every body knows that our Fingers are at liberty to execute different Motions, and to be extended ſeparately, tho' not only the Nerve, but alſo the Muſcle ſubſervient to their Extenſion is but one: Whence therefore this Liberty ſhould be denied our Eyes, whoſe Muſcles are diſtinct, I ſee not. But this is not all; for there are many Parts of the Body, which, tho' they have Nerves of different Origins, yet they neceſſarily move together. Thus the Eyes cannot be turned up nor down, but the Eye-lids follow their Motion, and keep at the ſame Diſtance from the Pupil, tho' at the ſame time the Eye-lids can be moved without any Motion in our Eyes. Did this uniform Motion depend upon any Union or Conjunction of the *Oculorum Motorii*, or of any of our other Nerves, none would ſquint, but ſuch as had them disjoined; and it would be in vain to uſe any Precaution againſt Children's taking up ſuch a Habit, or to endeavour to correct it.

§ 23. The true Cauſe of this Uniformity in the Motions of our Eyes to me ſeems wholly to depend on Cuſtom and Habit: For it is not to be doubted but theſe Motions are voluntary, and depending upon our Mind, which, being a wiſe Agent, wills them to move uniformly, not from any intrinſical Neceſſity in the Thing itſelf, or for want of Power to move them differently; but becauſe ſuch Motions are moſt profitable and uſeful to us. So that our Opinion is, that the uniform Motion of our Eyes is not at firſt neceſſary, but that the Mind has impoſed upon itſelf that Law, founded upon the Utility and Advantage that ariſes from this Sort of Motion; which Motion does in Time become ſo neceſſary, that none of us are now able to move one Eye towards any Object, but the other is likewiſe turned the ſame Way. And as for other Creatures who move their Eyes differently, ſuch as the *Chameleon*, which has this Faculty in an eminent Manner, ſo that the one Eye is moved, whilſt the other remains immoveable; the one is turned forwards, at the ſame time the other looks behind; and the one looks up to the Sky, when the other is fixed on the Ground. I ſay, as for other Creatures that move their Eyes differently, ſuch as the Hare, Chameleon, *&c.* it is evident, ſince the Organs ſubſervient to thoſe Motions are the ſame as in Man, that it is the Utility and Advantage they receive from theſe particular, Motions, which determines that Principle, which governs and rules all their Motions, to actuate the Organs in ſuch a Manner as thoſe Motions, which they find moſt profitable and neceſſary for them, may follow.

Dr. GODDART (in the *Philoſophical Tranſactions*) has obſerved, that the Eyes of the *Chameleon* reſemble a *Lens* or convex Glaſs, ſet in a verſatile globular Socket, of which our *Pariſian* Academiſts have taken no Notice. But, be this as it will, they found that they were moved by true Muſcles, which, as in other Creatures, are inſerted under the *Conjunctiva;* ſo that it ſeems PANAROLUS was miſtaken, when, as BARTHOLIN informs us, (*Hiſt. Anat. Rar. Cent.* 2. *Hiſt.* 62.) he ſays, that their Eyes want Muſcles, and that they are moved by the Corrugation of a Membrane, which is contracted by means of circular Fibres. What might have led him into this Miſtake, may be gueſſed at from the Obſervations of the ſame Academiſts, who tell us, that the Eyes, which are very large, jut out full Half of their Ball, and are covered with one ſingle Eye-lid, made like a Cap pierced through the Middle, with a Hole not exceeding one Line in Breadth. This Eye-lid was found faſtened to the Fore-part of the Eye, by means of an orbicular Muſcle that was ſpread over the whole *Tunica conjunctiva*, to which, as well as to the Eye-lid, it was ſo adherent, that it ſerved to give the ſame Motion to the Lid as to the Eye, tho' its particular Action was to contract the little round Hole of the Lid, which cloſes by enlarging itſelf croſs-ways, even to the making one ſingle Slit, which very exactly unites the upper Part with the lower. Seeing then that the

Eye cannot be moved, without communicating the ſame Motion to the Eye-lid, which muſt therefore appear corrugated, it is probable, that PANAROLUS, for want of due Scrutiny after the Muſcles, might have imagined that the Motions of the Eye proceeded from the Corrugation of this Membrane, which is indeed contracted by means of the circular Fibres of the orbicular Muſcle. But, ſuppoſing PANAROLUS's Obſervation to have been juſt, it is all one with reſpect to the preſent Caſe; for the diſſimilar Motion of the Eyes ariſing from the diſſimilar Contraction of thoſe circular Fibres, can have no Foundation, but in the Utility and Advantage that ariſes from ſuch Motions, which might as well have been executed by Muſcles. Nor can any good Reaſon be aſſigned, why the Mind, which preſides over all the animal (*if not alſo the vital and natural*) Motions, ſhould not be at Liberty to contract this or that Muſcle independently of others, as well as to contract this or that Fibre independently of others, eſpecially when we find it frequently does ſo in other Creatures, ſuch as Fiſhes, Birds: And, amongſt Quadrupeds, the Hare, Coney, *&c.*

And as the Hare, Coney, Chameleon, *&c.* have a Power of moving their Eyes differently, ſo neither is their any Room to doubt, but that at firſt we ourſelves are alſo poſſeſſed of the like Power; as is evident from an Obſervation made on Children, who, we ſee, for ſome Time after Birth, can look different Ways with their Eyes; which Power they retain, till, by diſcovering the Advantage of directing them the ſame Way, they come to move them always uniformly. This uniform Motion, by Uſe and Habit, at laſt becomes ſo neceſſary, that the Eyes cannot be moved differently; long Cuſtom rendering many Actions neceſſary, which were not ſo eſſentially, nor from the Beginning.

I have already given an Example of this in the Motions of the upper Eye-lid, which always follows the Motions of the Eye, and keeps at the ſame Diſtance from the Pupil, whether the Eye be turned up or down. The ſame Thing may alſo happen the Fingers; for, if one is not accuſtomed to move any of them but in Conjunction with the reſt, it will not be in his Power to move them ſeparately. Hence it is that moſt People cannot bend their Ring-finger towards the Palm of their Hand, but the little one ſhall follow its Motion. If any Body deſires more Examples of this kind, let him try to elevate one of his Eye-brows, while the other is depreſſed; let him try to dilate one of his Noſtrils, or one Side of his *Thorax*, while the other is contracted; or, if he can, let him contract the Muſcles on one Side of his Belly, while thoſe on the other Side continue relaxed. I remember a Time when it was very difficult for me to ſhut any one of my Eyes, while the other was open, which now is very eaſy for me, becauſe I have accuſtomed myſelf thereto; and this frequently happens, even in the Eyes themſelves: For, if we accuſtom ourſelves to direct them different Ways, as Boys do often in imitating thoſe that ſquint, we ſhall in time be able to ſquint without Difficulty, eſpecially if young. This is further confirmed from the diſſimilar Motions of the Eyes that are ſo frequently obſerved in blind People, and particularly by that Hiſtory, taken notice of by PLEMPIUS, of a Girl, who loſing her Sight, and having therefore no longer any Advantage from the uniform Motions of her Eyes, came at laſt to move them differently. Hence it is that Children, the younger they are, are the more apt to become gogle-ey'd; becauſe, when young, they have not ſo much accuſtomed themſelves to look the ſame Way with both Eyes, as to render that uniform Motion neceſſary; and therefore do frequently become gogle-ey'd, by having many pleaſant Objects preſented to them at the ſame time, which invites them to turn one Eye to one

Object, and the other Eye to another: And thus they contract a Habit of moving their Eyes differently, which is apt to continue all their Life-time, if not timely corrected. WILLIS has obſerved this (in his *Anima Brutorum, cap.* 15.) in theſe Words. *Quare infantes, quando ipſorum oculis multæ res ſimul objiciuntur, ſtrabiſmum facile contrahunt.*

CHAP. VI.

Of the Fabric and Structure of the Eye.

SECT. I. THAT we may the better underſtand the curious Fabric and beautiful Mechaniſm of this noble Organ, I ſhall firſt give a general Idea of its Sructure, and then ſhall conſider more particularly each Part by itſelf; and at the ſame time ſhall make ſome Remarks upon its different Make in different Animals.

§ 2. I have already obſerved, that the Globe or Body of the Eye is compoſed of Membranes or Tunicles, Humours and Veſſels.

The proper Tunicles and Coats of the Eye are nothing but ſo many Productions or Expanſions of the different Subſtances of the optic Nerve. The optic Nerves, like all the other Nerves of the Body, have three diſtinct Subſtances, whereof the two firſt are membranous Coats or Coverings, the one coming from the *Dura*, and the other from the *Pia Mater*; and the third Subſtance is a Continuation of the *Medulla Cerebri* itſelf. Theſe three different Subſtances, at the Bottom of the Eye, where thoſe Nerves enter the Globe, are expanded out into a ſpherical Figure, and form its Tunicles, which therefore are alſo three in number.

§ 3. The firſt ariſes from the external Coat which the optic Nerve has from the *Dura Mater*, and expands itſelf into almoſt an exact Sphere or Globe. It covers the whole Bulb of the Eye externally, and therefore is the largeſt of all its Coats; it is thick, opaque, and hard like Leather behind, and all round, till it comes to where the White of the Eye terminates, and is therefore called *Tunica Dura ſeu Sclerotica*; but its Fore-part beginning where the White of the Eye terminates, is thinner and perfectly tranſparent, and is called *Tunica Cornea*, becauſe it tranſmits the Rays of Light like the Horn of a Lantern.

Tho' this tranſparent Part of the outward Tunicle of the Eye has a diſtinct Name from its opaque Part, the firſt being called *Cornea*, and the ſecond *Sclerotica*, yet I ſcruple not to conſider them as one and the ſame Tunicle, expanded from the external Coat of the optic Nerve about the whole Globe. Nor do the Arguments that have been brought by ſome learned Anatomiſts to prove them diſtinct, appear ſufficient to demonſtrate that they are really ſo; as ſhall be noticed afterwards.

The tranſparent Part, called *Cornea*, which is what we ſee ſurrounded by the White of the Eye, is always more protuberant and convex than the reſt of the Eye, and therefore is elevated above the ſpherical Surface of its opaque Part called *Slcerotica*. But in different Animals this Protuberancy is not always the ſame. In Man, and the greateſt Part of Quadrupeds, the *Cornea*, according to MAITRE-JEAN, is a Part of a Sphere whoſe Diameter is an eighth Part leſs than that of the *Sclerotica*; but Birds have their *Cornea* much more elevated, it being, according to the ſame Author, a Part of a Sphere whoſe Diameter is only about the Half of the Diameter of their *Sclerotica*. I find indeed that MAITRE-JEAN is greatly miſtaken with regard to this Account he gives of the Convexity of the human *Cornea*, as ſhall be ſhown below from Dr. PETIT's more accurate Obſervations. Yet this does not make the *Cornea* in all Animals of a ſimilar Convexity; all Authors being agreed that

Birds have this Coat much more elevated and convex than either Man or Quadrupeds. According as our *Cornea* is more or leſs protuberant and convex; that is, according as it is a Part of a leſſer or greater Sphere, Objects appear greater or leſs, and more remote or nearer; for the Convexity of the *Cornea* has a ſimilar Effect to that of a convex *Lens*, thro' which, if an Object be viewed at a leſs Diſtance than the *Focus*, it appears bigger and more remote than it does to the naked Eye; ſtill the bigger and more remote, the more convex the *Lens* is thro' which it is ſeen: And as Objects are not ſeen diſtinctly, but when their Diſtance is ſuited to the Convexity of the Eye, this Difference in the Convexity of the *Cornea* will alſo occaſion the Sight to be ſhorter or longer, according as it is more or leſs convex.

§ 4. The ſecond Coat of the Eye ariſes from the ſecond Tunicle of the optic Nerve, and is alſo expanded out into a ſpherical Form, till it reaches the *Cornea*. It lies immediately within the *Sclerotica*, and lines its internal concave Surface, to which it adheres; but, at the Edge of the *Cornea*, where the *Cornea* joins the *Sclerotica*, this Tunicle ſeparates itſelf from this Membrane, and goes directly inwards towards the *Axis* of the Eye. That Part of it which lines the *Sclerotica*, is called *Choroides*;

but its Fore-part, extending from the Edge of the *Cornea* to the *Axis* of the Eye, is called *Uvea*; in the Middle of which is a round Hole called the *Pupilla* or *Sight*. This Coat is all over opaque, as well in its Fore-part called *Uvea*, as in its Back-part called *Choroides*; by which means the inward Eye is darkened, and no Rays can enter it but what paſs by the Pupil. As the *Uvea* is a plain Membrane cutting the Eye tranſverſely in that Circle where the *Sclerotica* joins the *Cornea*, there muſt be a Space left betwixt the *Cornea* and this Membrane lying behind it. This Space is filled with the aqueous Humour, a Part of which alſo lies behind the *Uvea*, and fills all the Space betwixt it and the cryſtalline Humour.

The Outſide of the *Uvea*, where the different Colours appear, is called the *Iris*, from its Reſemblance to the Rain-bow, both being compoſed of different Ranges of Colours: From theſe Colours the Eye is frequently named, and is called Blue, Gray, Black, *&c.* according to the Colour that is moſt predominant in the *Iris*.

§ 5. The third and laſt Membrane of the Eye is called *Retina*, becauſe, like a Net, it covereth the Bottom of the Cavity of the Eye. It is nothing but a fine Expanſion of the medullary Part of the optic Nerve.

Its convex or outward Side lines the *Membrana Choroides*, and its concave Side covers the Surface of the vitreous Humour.

This Tunicle ends where the *Choroides*, in going inward towards the *Axis* of the Eye, forms the *Uvea.* It is upon it that the Impreſſions of Objects are made, and therefore it is juſtly reckoned the immediate Organ of Sight; tho' the learned MARIOTTE is of another Opinion, and contends, that it is the *Tunica Choroides* which receives theſe Impreſſions. His Arguments ſhall be noticed afterwards in their proper Place.

§ 6. The Humours of the Eye fall next to be conſidered; they are three in number, the *Aqueous*, the *Cryſtalline*, and the *Vitreous*. All of them are tranſparent, that none of the Light may be intercepted, but that all of it may be tranſmitted for painting the Images of Objects upon the *Retina* with ſufficient Strength and Brightneſs. They are alſo all clear like Water, that the Images of Objects may be ſeen in their own proper Colours; for, were they tinged with any Colour, the Objects would alſo appear tinged with that Colour: For tho' Objects are ſeen very diſtinctly when this Tincture does not render the Humours opaque, yet they muſt appear in the ſame Manner as to an Eye that is perfectly ſound, when it looks at them thro' a Glaſs tinged with the like

Colour. Thus in Jaundices the Eye is frequently ſo much tinged with the yellow Colour of the obſtructed Bile, that all Objects appear tinged with the ſame yellow Colour.

§ 7. But it is to be obſerved, that we are never ſenſible of this Change of Colour, unleſs the Tincture be conſiderable, and that it happen on a ſudden. It muſt be conſiderable, that the Difference of Colour may be ſenſible to us; and it muſt happen on a ſudden, that our Memory may retain the Remembrance of the Colours wherewith Objects appeared coloured, in order to make a Compariſon, when, after that, we again look on the ſame Objects.

There is nothing to which our Eyes do more ſpeedily accuſtom themſelves, than to the Change of Colours. It is eaſy for every body to experience this, by looking thro' a Glaſs tinged with Green, or any other Colour, and at the ſame time hiding the Objects which might be ſeen without the Interpoſition of the Glaſs; for, in a very little Time, it cannot be perceived that the Objects are tinged with the Colour of the Glaſs; and we will be yet leſs ſenſible of the tinging of Objects, if our Eyes are kept a conſiderable time ſhut before the Experiment is made.

Hence it follows, that none of us can be abſolutely certain, that any Object does now appear to us of the ſame preciſe Colour of which it appeared a Month or a Year ago. And this is ſtill the more evident, if we conſider that Objects appear of different Colours according as they are illuminated with different Lights; of which nevertheleſs we are commonly altogether inſenſible.

Thus the greateſt Part of Objects, in Candle-light, are always tinged with a yellow Red, tho' we are not ſenſible thereof; becauſe all the Objects in view are changed in the ſame Proportion. But if, in the Day-time, you place Candles in a darkened Chamber, that every thing therein may be well illuminated, and then retire to another Place illuminated with the Sun's Light, the Objects illuminated with Candle-light, when viewed thro' the Door of the Room, will appear tinged with a yellow Red, when compared with thoſe that are ſeen at the ſame time illuſtrated with Day-light. But this cannot be obſerved, when one is in the Chamber in which the Candles are placed; and therefore it is no Wonder we are not ſenſible of the Changes which may happen in our Senſation of Colours, either from the various Diſpoſitions of our *Retinæ* and optic Nerves, or from the Tincture with which the Humours of our Eyes may be inſenſibly tinged.

§ 8. And, if we are not ſenſible of the Change of Colours, we can never be certain that the Colours of Objects are not changed; that is, we can never be certain that an Object does now appear to us of the ſame preciſe Colour of which it appeared laſt Day, or laſt Week: Neither can our being inſenſible of any Change ever prove to us that the Colour is the ſame. So that it is evident, not only that different Perſons may have different Senſations of Colours, proceeding from the different Diſpoſitions of their optic Nerves and *Retinæ*, or from the different Tinctures wherewith their Eyes are tinged, but alſo that the ſame Perſon may, from the ſame Cauſes, ſee the ſame Object differently coloured, at different times, without being ſenſible of it.

§ 9. But this is not all; for Experiments are not wanting, whereby it appears, that the ſame Object is ſeen of different Colours, according as it is viewed with the right or left Eye.

When theſe Colours are very different, it is eaſy to perceive the Difference, by ſhutting the Eyes alternately. Thus, after one has for ſome time viewed a very luminous Body thro' a Teleſcope, it is eaſy to obſerve that Objects appear a great deal darker to that Eye than to the other that was kept ſhut. It is eaſy to make this Experiment in the Twilight, by looking alternately with both Eyes to a white Wall or Sheet of white Paper after one has viewed the Moon with a Teleſcope. The

Reaſon of this *Phænomenon* can be nothing but the Contraction of the Pupil occaſioned by the great Light; for the Brightneſs of the Object makes it ſhut up as much as poſſible: But the Pupil of the ſhut Eye will be much larger, becauſe it contracts only by Sympathy, and therefore it muſt allow a greater Number of Rays to enter, which will make the Object appear whiter to this Eye than to the other: And beſides this, we might alſo add, that the *Retina* of that Eye to which the Teleſcope was applied, having been ſtrongly agitated by the great Light, cannot preſently be ſufficiently agitated by that of an Object moderately illuminated; and this may be another Reaſon why the Object appears more white and luminous to the Eye that was ſhut, than to the other that viewed the Moon thro' the Teleſcope. But it is carefully to be obſerved, that, if the white Wall or Paper that one looks at, after viewing the luminous Body with the Teleſcope, be ſtrongly illuminated, as with Day-light, the Experiment will not ſucceed; for the great Light of the Object will touch the *Retinæ* of both Eyes ſo ſenſibly, that we cannot diſtinguiſh any Difference in the Impreſſions, or in the Senſations ariſing therefrom. Thus we ſee, that the Difference of Colours which appears in Objects, according as they are viewed with different Eyes, is eaſily diſcovered, by ſhutting the Eyes alternately, when this Difference is conſiderable.

But it is more difficult to know if the ſame Object is ſeen of different Colours with both Eyes, when their Difference is ſmall: Yet the learned Monſ. *De la* HIRE has given us a Method whereby the leaſt Difference may be eaſily known. His Method is as follows.

Take two Cards, and in each of them make a ſmall round Hole with a Pin, whoſe Diameter does not exceed the third or fourth Part of a Line; then apply them to your Eyes, and thro' the Holes look at a Sheet of white Paper that is all over equally illuminated: Each Eye ſhall ſee a Circle of Paper thro' the Holes, and thoſe Circles will coincide and appear one, if the Rays that come from the ſame Point of the Object, after paſſing the Holes of the Cards, are, by the Humours of the Eyes, ſo refracted, as to meet in the Bottom of both Eyes in analogous Points. But, if the Poſition of the Cards be changed, you ſhall ſee two diſtinct Circles of Paper ſeparated from each other; and therefore, by ſeparating the Cards, or bringing them nearer together, it is eaſy to make the two Circles of Paper which are ſeen thro' the Holes touch on another; and conſequently it will be eaſy to make a Compariſon betwixt their Colours. If both Eyes are perfectly ſimilar, the Colours of theſe Circles will alſo appear ſimilar; but if the Humours of the Eyes are unequally tinged, or if the *Retinæ* are not of the ſame Diſpoſition, and equally ſenſible of the Impreſſion of Objects, theſe Circles will ever appear of different Colours.

§ 10. By this Experiment, *De la* HIRE has obſerved, that thoſe who ſee Objects more ruddy with one Eye than the other, eſteem that Eye the beſt for ordinary Uſe; and therefore it is probable, that that Redneſs is owing to the Delicacy and greater Mobility of the *Retina* of that Eye, which being more ſtrongly agitated by the Rays of Light than the other, makes the ſame Object appear to it more ruddy; for, according to Sir ISAAC NEWTON's Theory, the leaſt refrangible Rays do excite the largeſt and ſtrongeſt Vibrations in the nervous Coat of the Eye, for making a Senſation of a deep Red; the moſt refrangible, the ſhorteſt and weakeſt, for making a Senſation of a deep Violet; and the ſeveral intermediate Sorts of Rays excite Vibrations of ſeveral intermediate Bigneſſes and Strength, to make Senſations of the ſeveral intermediate ſimple Colours; and therefore it is reaſonable to ſuppoſe, that the *Retina* of that Eye to which Objects appear more ruddy than to the other, is more delicate and moveable; from which Mobility the Vibrations will be ſtronger for cauſing that ruddy Appearance, and the Eye itſelf will be more ſenſible, and will therefore be eſteemed the beſt. But to return,

§ 11. Theſe three Humours are different in Conſiſtency, as well as in Quantity. The moſt fluid is called the *Aqueous*, becauſe it approaches the Nature of Water, as well in Conſiſtency as in Tranſparency.

This Humour lies partly before and partly behind the *Uvea*, and fills all that Space which is betwixt the *Cornea* and cryſtalline Humour. With regard to its Quantity, the greateſt Part of Authors have been greatly miſtaken. The great VESALIUS, by placing the Cryſtalline in the Middle of the Eye, increaſes the Quantity of this Humour greatly above what it really is. DIEMERBROEK tells us, it is equal to the third or fourth Part of the Vitreous; whereas he makes the Cryſtalline only the fifth or ſixth Part of the Vitreous, by which the Quantities of the *aqueous*, the cryſtalline and vitreous Humours, will be to one another, at a Medium, in the Proportions of $5\frac{1}{2}$, $3\frac{1}{2}$, and $19\frac{1}{4}$; which, in Integers, is 22, 14, and 77. The famous BARTHOLIN ſays, that the aqueous Humour is equal to one half, and the Cryſtalline to one fifth of the vitreous Humour, by which their Quantities will be as the Numbers 2½, 1, and 5. Dr. BRIGGS makes them to one another, as the Numbers 1, 2, and 24. But the learned Dr. PETIT, of the Royal Academy of Sciences, who, on occaſion of the Diſpute concerning the Nature of Cataracts, made the Eyes his particular Study, and whoſe Experiments and Obſervations were made with ſo much Care and Exactneſs, and ſo often repeated, that they may be depended on more than any thing that is to be found in moſt other Authors; this Author informs us, in the *Mem. de l'Academ. An.* 1728, that, in a Man of 50 Years of Age, the aqueous and cryſtalline Humours were each four Grains, and the vitreous a hundred and four Grains; ſo that the aqueous, cryſtalline and vitreous Humours were to one another in this Eye, as the Numbers 1, 1, and 26. In the Eye of another Man of 22 Years, the Aqueous and Cryſtalline were alſo four Grains each, but the Vitreous was only 95 Grains; ſo that their Weights, in this Man's Eye, were to on another, nearly in the Proportion of 1, 1, and 24. And therefore the Weight of theſe Humours in the human Eye may be reckoned, at a Medium, to be to one another nearly as 1, 1, and 25. In other Creatures this Proportion varies. In a Cow, the ſame Author obſerved the aqueous Humour to be 38 Grains, the Cryſtalline 52, and the Vitreous 360; and therefore they are to each other in the Proportion of 1, $1\frac{7}{19}$, and $9\frac{9}{19}$. In another Cow, whoſe Eyes were a little withered, their Weight was 34, 54, and 347 Grains, which are to one another nearly, as in the former Caſe, regard being had to the withering of the Eye, in which the aqueous Humour always loſes moſt by Evaporation.

§ 12. The ſecond Humour of the Eye is called the *Cryſtalline*, becauſe it reſembles the pureſt Cryſtal in Tranſparency. It is not the leaſt of all the Humours, as has been generally taught, the Aqueous and it being of equal Weights, as has been already obſerved: But its Subſtance is by much the moſt firm and ſolid of any of them. It is of a lenticular Figure, being convex upon both Sides; but its Fore-part, which looks to the Pupil, is not ſo convex as its other Side next the glaſſy Humour. It is covered all over with a very fine tranſparent Coat or *Capſula*, which, from its Fineneſs, is called *Aranea*.

This Humour is ſituated exactly behind the Pupil, but not in the Middle of the Eye, where VESALIUS places it, but a good deal nearer its fore than back Part. Its *Axis* coincides with the *Axis* of the Eye. The aqueous Humour fills up all the Diſtance betwixt it and the *Cornea*, as the vitreous does that betwixt it and the *Retina*. We have ſaid, that this Humour is convex upon both Sides, and that its Back-part is the moſt convex: Now, this Convexity of its poſterior Face, is all received into an equal Concavity in the Fore-part of the glaſſy Humour.

§ 13. The third Humour of the Eye is the *Vitreous*, ſo called, becauſe it reſembles melted Glaſs. It is the largeſt of all the Humours; for it filleth all the Back-part of the Cavity of the Globe. It is much thicker than the aqueous, but thinner than the cryſtalline Humour. Upon its back Part the *Retina* is ſpread, which it holdeth from the cryſtalline Humour at a Diſtance requiſite to receive the Impreſſions of Objects diſtinctly, and in the *Focus* of the Rays: The Middle of its Fore-part has a Dimple or ſmall Cavity in which the whole poſterior Face of the Cryſtalline lies, as has been before obſerved. This Humour, as well as the Cryſtalline, has a very fine Coat which covers it all round: It is called *Tunica vitrea*, from its Office. This Tunicle, at the Edge of the Cryſtalline, is devided into two Membranes, of which the one is continued over the whole anterior Part of the vitreous Humour, and covers that Dimple or Cavity in which the convex Back-part of the Cryſtalline lies; the other paſſes above the Cryſtalline, and covers all its Fore-part, by which means theſe two Humours are cloſely attached together; as may eaſily be obſerved, after they are taken out of the Globe; for they adhere ſo cloſely, that they are nor to be ſeparated without ſome Force.

§ 14. Beſides the Tunicles and Humours of the Eye already deſcribed, there is yet another Part, which, tho' very delicate and ſmall, yet is of conſiderable Uſe in ſeeing Objects diſtinctly at different Diſtances. It is called *Ligamentum Ciliare*, becauſe it is compoſed of ſmall Filaments or Fibres, not unlike the *Cilia* or Eye-laſhes.

This Ligament, or rather muſcular Proceſs, is made up of ſhort white Fibres, which ariſe from the Inſide of the *Choroides* all round its circular Edge, where it joins the *Uvea*; from which Orgin they run upon the Fore-part of the glaſſy Humour, like Lines drawn from the Circumference to the Centre, and terminate all round at the Edge of the Cryſtalline, being attached to the Membrane of the vitreous Humour at that Place, where it devides to cover the Cryſtalline.

Theſe Fibres are at ſome Diſtance from one another. But the Intervals are filled up with a blackiſh Sort of *Mucus*, which makes the whole appear like a black Membrane.

§ 15. This is a general Idea of the Structure of the Eye, which we thought neceſſary to premiſe, for the ſake of thoſe that are but little acquainted with this Organ. For the better underſtanding of which, ſee the Section of the Eye at FIG. 4. PLATE I. where,

NOO repreſents the optic Nerve.

The outmoſt Line OSCSO is the external Coat of the Eye, whoſe Back-part SOOS is the *Sclerotica*, and whoſe Fore-part SCS is the tranſparent *Cornea.*

The Line OSPSO lying immediately within the former, is the ſecond Coat of the Eye. Its Back-part SOOS is the *Choroides*, and its Fore-part SPS is the *Uvea*, in which the Hole at P is the Pupil.

The prick'd Line SOOS is the *Retina.*

The Cavity SCSRRS is the aqueous Humour.

The lenticular Figure RR is the Cryſtalline.

All the Space SOOSRRS, lying behind the Cryſtalline, is the vitreous Humour.

SR, SR, is the *Ligamentum Ciliare.*

CHAP. VII.

Of the Sclerotica *and* Cornea.

HAVING, in the laſt Chapter, given a ſhort Account, of the conſtituent Parts of the Eye, I now proceed to conſider thoſe Parts more particularly: And, *firſt* Of the *Sclerotica* and *Cornea*.

§ 1. The *Sclerotica* and *Cornea*, as we have before obſerved, are one and the ſame Coat, being nothing but a Production or Expanſion of the outward Tunicle of the optic Nerve; yet ſome Authors are greatly offended with this ſuppoſed Continuity, and that becauſe, *Firſt*, If they were a Continuation, of the Tunicle, which the Nerve has from the *Dura Mater*, then, ſay they, they would be endowed with a Senſe much more exquiſite than what they are poſſeſſed of, and the Puncture made in the *Sclerotica* in couching the Cataract would be unſupportable; whereas it produces only a very ſlight Pain, tho' this Membrane is not only pretty hard, but alſo of a conſiderable Thickneſs.

§ 2.

§ 2. That this Membrane is not very ſenſible, is moſt certain; and it is probable, that the couching of the Cataract would ſcarce give any Pain at all, were not the Membranes that compoſe the White of the Eye pricked at the ſame time, which Membranes are indeed endowed with a very exquiſite Senſe; but being thin, they are quickly pierced with the Needle, and therefore the Pain, becauſe ſoon over, becomes ſupportable. But from this it does not follow, that the *Sclerotis* and *Cornea* are not one continued Subſtance with the outward Membrane of the optic Nerve; for, in ſeveral Parts of the Body, we obſerve the ſame continued Subſtance endowed with different Degrees of Senſibility; and particularly the Nails have no Senſe at all, tho' according to the Obſervation of ſome Anatomiſts, and thoſe none of the meaneſt Rank, they are of one continued Subſtance with the Nerves themſelves from which they ariſe.

§ 3. A *ſecond* Argument againſt the Continuity of the outward Coat of the Nerve with the Subſtance of the *Sclerotis* and *Cornea*, is, That, were it ſo, then, in Birds and Fiſhes that have the *Sclerotis* converted into a hard bonny Subſtance, the external Membrane of the Nerve, as well as the *Cornea*, would alſo be found bonny or cartilaginous;

which not being fact, they conclude it a groſs Error thus to deſcribe thoſe Tunicles as an Expanſion of the outward Coat of the Nerve.

§ 4. But from this Way of reaſoning they might as well find fault with deſcribing the *Baſis* of the *Aorta* next the Heart as one continued Subſtance with all the Arteries of the Body, becauſe in ſeveral Animals it is found bonny, tho' at the ſame time all the reſt of its Subſtance, as well as that of the other Arteries ariſing therefrom, is membranous and yielding.

Every body allows, that the Tendons are of one continued Subſtance with their Muſcles; which could not be true, were this kind of reaſoning concluſive; for the Tendons of the Thighs and Legs of Birds grow bonny, as they grow old; whereas their reſpective Muſcles always continue fleſhy, ſoft and flexible. We have therefore, after the Manner of many Anatomiſts, taken the Liberty to deſcribe this and the other Coats of the Eye as Continuations or Expanſions of the different Subſtances of the optic Nerve, partly becauſe ſuch a Suppoſition contributes to the clearer deſcribing theſe Coats, and partly becauſe they are ſo cloſely united with theſe Subſtances, that they cannot be ſeparated without cutting them; which is all we ſhall offer as an Apology,

logy, leaving every body at Liberty to think otherwiſe, if they incline; it being a matter of no great Conſequence, with regard to what I am to ſay, whatever Opinion they embrace.

§ 5. Now, this external Coat of the Eye is compoſed of Fibres, which do not run the ſame Way, but croſs one another in a Multitude of Places, and almoſt every where: Hence it is that it is very difficult to tear this Membrane ſtreight, the different Directions of its Fibres in different Places making it tear different Ways, ſo as to appear ragged.

§ 6. It is, like all the other Membranes of the Body that are of any conſiderable Thickneſs, compoſed of different Plates or Pellicles applied over each other: Theſe Plates are very difficultly ſeparated in the *Sclerotis*, becauſe of the many Fibres and Veſſels which running croſs betwixt its two Sides tie them together; but in the *Cornea* they may be ſeparated with much more Eaſe; for with the Point of a Lancet you can eaſily raiſe three, four or five ſuch Pellicles, each of which may again be ſuppoſed to be compoſed of many others; for LEEUWENHOEK, in the *Cornea* of a Calf, ſeparates no leſs than a hundred of them.

§ 7. Some Anatomiſts will not allow this Membrane to be compoſed of different Pellicles, and contend that theſe anatomical Separations are rather Diviſions of what was naturally united and continuous. But, beſides what appears in Diſſection, we have a demonſtrative Proof of this from what happens in Puſtules and Abſceſſes of the *Cornea*; for theſe little Tumours do not only appear broad and flat, but frequently the Matter contained in them makes its Way betwixt the Pellicles, and falls down to the lower Edge of the *Cornea*, leaving behind it a Spot or Mark, which, if oppoſite to the Pupil, does very much darken the Sight, if not properly treated. Now, were the *Cornea* of one continued homogeneal Subſtance, the Humour finding an equal Reſiſtance on all hands, would always form a round convex Tumour: But ſince theſe Tumours are flat and broad, and ſince the Matter frequently makes its Way in the Manner juſt now obſerved, it neceſſarily follows, that it lies betwixt its Pellicles which, by ſeparating from one another where the Reſiſtance is leaſt, give the Tumor a broad flat Form, and allow it to paſs betwixt them to the under Edge of the *Cornea*; which could not happen, were it of one continued homogeneal Subſtance; and therefore it muſt be allowed to be compoſed of many Pellicles or Plates applied one upon another.

§ 8. In Man and Quadrupeds, both the *Sclerotica* and *Cornea*, tho' of a denſe compact Subſtance, are nevertheleſs ſoft, flexible and yielding, like other Membranes. But, in Birds and Fiſhes, the *Sclerotica* is altogether inflexible, being generally harder than a Cartilage, and in ſome quite bonny; whence it ſeems manifeſt, that in theſe Creatures the Change of the Conformation of the Eye, by which it is adapted to the different Diſtances of Objects, does not ariſe from any Change in the Figure of the Eye itſelf, proceeding from the Action of its Muſcles, as many have imagined; the Hardneſs and Inflexibility of the *Sclerotica* being repugnant to any ſuch Change of Figure, from whatever Cauſe it may be ſuppoſed to ariſe. This Change of Conformation in the Eyes of theſe Creatures muſt therefore proceed from ſome other Cauſe, ſuch as the Contraction of the *Ligamentum Ciliare*; and if this Ligament can have this Effect in thoſe Creatures, I ſee not why the ſame Power ſhould be denied to it in Man and Quadrupeds, or why we ſhould ſeek for the Cauſe of this Change any where elſe.

In Fiſhes, Inſects, and all ſuch Animals as want Eye-lids to cover and defend their Eyes, the *Cornea* alſo is of a firm hard Subſtance, as has been obſerved by FABRICIUS *ab Aquapendente*,

pendente, which was neceſſary, that it might not be hurt by ſuch Particles as their Eyes are expoſed to, and from which the Eyes of other Animals are ſo well guarded and defended by their Eye-lids. This is particularly to be obſerved in cruſtaceous Animals, ſuch as the *Locuſta*, *Gammarus*, *Pagarus*, *Cancer*, &c. in whom Eye-lids, in place of being uſeful or neceſſary, would have been hurtful, and an Impediment to their Sight; for, as hath been before obſerved, had Nature extended their hard cruſtaceous Skins over their Eyes, in form of Eye-lids, they could not have been moved to and again upon their Eyes; and, were it poſſible they could be moved, they would neceſſarily hurt the tender Eye, in place of defending it: Therefore, provident Nature has wiſely contrived another Method by which their Eyes might be ſecured from external Injuries, and that is, the Hardneſs of the *Cornea*, which, in theſe Animals, exactly reſembles the Horn of a Lantern; and therefore is not to be hurt by ſuch Particles as their Eyes are commonly expoſed to. In other Animals, that want Eye-lids, the *Cornea* is alſo commonly firm and hard, tho' not ſo firm as in cruſtaceous Animals. But, in all Animals that are provided with Eye-lids for guarding and defending their Eyes, ſuch as

Man, Quadrupeds and Fowls, their *Cornea* is more ſoft and delicate.

§ 9. The accurate Mr. WINSLOW having obſerved that the *Cornea*, after Death, is commonly covered with a kind of Membrane or fine glairy Coat, which ſometimes tarniſhes the Eye to ſuch a Degree, that the Pupil can ſcarcely be diſtinguiſhed; and obſerving, that this Membrane is to be found as well in thoſe who die with their Eyes open, as ſhut, was made to ſuſpect, that it was formed of a Lymph that naturally ſweated thro' thoſe Pores of the *Cornea*, which STENO had made mention of in his Treatiſe on the Glands and Muſcles; and, after many fruitleſs Attempts to diſcover theſe Pores, he was at laſt ſo lucky as to ſucceed: For, by preſſing the Eye in a certain Manner, which he lighted on by accident, he could diſtinctly ſee this Liquor ſweat thro' theſe Pores, and form little Drops upon the *Cornea*, which gradually diffuſed themſelves over its whole Surface. (See *Mem. de l'Academ. ann.* 1721.)

This glairy Coat is very tender and delicate, in ſo much that it breaks into many Pieces when it is touched, and is eaſily removed altogether by wiping the *Cornea*. It commonly begins to be formed ſome little time before Death; whence the Eyes loſe their Brilliancy, and becoming dull and lifeleſs, put on a certain Appearance which has always been looked on as a certain Sign of a ſpeedy Diſſolution. It is not therefore without ſome Reaſon, notwithſtanding what PLEMPIUS ſays to the contrary, that PLINY tells us, that while the Pupil reflects Images, Death is not to be feared. (*Vid. lib.* xxviii. *cap.* 6.)

§ 10. It has been noticed before, that MAITRE-JEAN makes the human *Cornea* a Part of a Sphere whoſe Diameter is only one eight Part leſs than that of the *Sclerotica*. But in this he is greatly miſtaken, it being much more convex. The great HUGENS, in his *Dioptricks, prop.* 31. makes the Diameter of the Eye about an Inch of the *Reinland* Foot, which is much the ſame as the old *Roman* Foot, and the Diameter of the outward *Cornea* about three fifth Parts of an Inch. This is pretty near the Truth; for Dr. PETIT has ſhewed that the *Axis* of the Eye meaſures 11 $\frac{1}{3}$ Lines *Paris* Meaſure; whereas the Diameter of the Sphere of which the *Cornea* is a Part, is commonly only 7, 7$\frac{1}{4}$ or 7$\frac{1}{2}$ Lines.

The Chord of the *Cornea*,, or, which is the ſame thing, the Diameter of the *Iris*, including the Thickneſs of the *Cornea*, commonly meaſures from 5 to 5$\frac{1}{4}$ or 5.$\frac{1}{2}$ Lines. (*l'Hiſtoire de l'Academ. Royal, ann.* 1728.)

The Diſtance betwixt the Centre of the *Cornea* and the cryſtalline *Lens*, meaſured on the

Axis of the Eye, from the Outſide of the *Cornea*, is $1\frac{5}{12}$, from which deducing $\frac{2}{12}$, which is the Thickneſs of the *Cornea* itſelf, there remains $1\frac{1}{4}$ for the Thickneſs of both Chambers of the aqueous Humour.

The Thickneſs of the Fore-chamber of this Humour, or the Diſtance betwixt the Centre of the *Cornea* and the Centre of the Pupil, he found to be 0.955; but the Thickneſs of the poſterior Chamber, or the Diſtance betwixt the Centre of the Pupil and the Cryſtalline, he found to be a good deal leſs, being only 0.32; which two being added together, give 1.275 for the Thickneſs of both Chambers, which is nearly $1\frac{1}{4}$, as has been before obſerved.

§ 11. From this great Thinneſs of the poſterior Chamber of the aqueous Humour, it is obvious, that, in the Operation of the Cataract, the Needle can never paſs into this Chamber, without hurting the *Iris*, whoſe Diſtance from the Cryſtalline being leſs than the Third of a Line, can never allow of that Motion of the Needle that is neceſſary for depreſſing the Cataract, without tearing that delicate Membrane.

I know that a great many Operators, and even MAITRE-JEAN himſelf, have imagined, that the Needle is introduced before the Cryſtalline, betwixt it and the *Iris*; having been led, as I ſuppoſe, into that Miſtake, from their ſeeing the Needle thro' the Pupil. But the Opacity of the Cryſtalline is not ſo great, but that the Needle, which is always introduced behind it, may be ſeen thro' this Humour; for I take the Opacity of the Cryſtalline to be in this reſpect ſomewhat analogous to oiled Paper, thro' which, tho' an Object cannot be ſeen when placed at a Diſtance behind it, yet it may be ſeen pretty diſtinctly when made to touch it. And, to be yet further convinced that the Needle is introduced behind the Cryſtalline, we need only compare the Place of the Puncture and the Direction of the Needle, with the Situation and Thickneſs of the cryſtalline *Lens*.

From what hath been ſaid, it is eaſy to ſee, that the Cataract cannot be a Pellicle or Film ſwimming in the aqueous Humour, as was generally believed, till towards the Beginning of this Century, that BRISSAW, MAITRE-JEAN, HEISTER, *&c.* ſhewed it to be an Opacity of the Cryſtalline: For, were it a Film in the aqueous Humour, it could not be couched by the Operation, as it is commonly performed, becauſe the Needle never enters the Place of that Humour. We may from this alſo ſee one good Reaſon why ſometimes this Operation does not ſucceed ſo well as might be expected; for, if the Operator miſtakes the Situation of his Needle, and imagines that it is before the

Cataract or opaque Cryſtalline, he may loſe much Time and Pains in poking and ſearching for the Cataract, before he can depreſs it; by which laborious Operation, the Eye muſt ſuffer conſiderably, which is apt to render the Operation fruitleſs: And tho' the Operation ſometimes ſucceeds, even when the Operator miſtakes the Situation of the Needle, yet it cannot be denied, that the opaque Body forming this Diſeaſe, will be the more eaſily, quickly and effectually depreſſed, that its Situation with reſpect to the Needle, and the Anatomy of the Eye, are exactly known.

§ 12. This external Coat of the Eye, contrary to the Opinion of LAURENTIUS, has Arteries, which ariſe from that Branch of the *Carotid* which accompanies the optic Nerve in going out of the Skull; and Veins, which diſcharge themſelves into the Jugulars. The moſt conſiderable of theſe Veſſels enter it upon its Back-part near the optic Nerve, where they form different Ramifications, of which ſome are extended thro' this whole Coat, and terminate betwixt its Pellicles; others pierce its Pellicles obliquely, and enter the Globe itſelf, for to be diſtributed to the *Choroides*, *Uvea*, *Retina*, and its other internal Parts.

Beſides theſe Veſſels, there are inſerted into this Membrane ſome Branches of Nerves which come from the ophthalmic Branch of the fifth Pair. Theſe Branches having accompanied the optic Nerve, are diſtributed partly to the Bottom of this Membrane, and are diffuſed thro' all its Subſtance. The reſt do pierce it intirely in other Places, and are beſtowed upon the *Choroides*, Ciliary Circle, *Uvea*, *&c.*

CHAP. VIII.

Of the Choroides *and* Uvea.

SECT. I. THIS Coat lies immediately within the former, and, as has been ſaid before, is nothing but an Expanſion of that Membranous Covering which the optic Nerve receives from the *Pia Mater*: It is a great deal thinner than either the *Sclerotica* or *Cornea*; and, being very delicate and tender, is eaſily torn aſſunder: Its Fore-part, called *Uvea*, is much thicker and ſtronger than its Back-part, called *Choroides*; and this Thickneſs is ſuppoſed to ariſe from ſome circular Fibres that are ſpread upon its outward Part for contracting the Pupil: Yet at its Edge, where it forms the Pupil, it is very thin and tender; and therefore great Care ought to be taken in couching the Cataract, that it be not torn by the Needle, which, when it happens, the Magnitude and Figure of the Pupil will be for ever changed.

§ 2. This Coat is quite opaque in all its Parts; by which means it allows no Light to paſs but what enters by that circular Hole in its Fore-part, called the *Pupil*: And this Opacity is yet more increaſed by that black Pigment, with which it is all over covered, and which makes this Membrane appear black, tho' it be really white, as every body may be aſſured of, by ſcraping and waſhing off this Colour, which eaſily ſeparates. But this Membrane is not over all equally covered with this Colour: It is in greater Plenty in the Back-part of the *Choroides*, which touches the *Sclerotis*, and in the inner or poſterior Side of the *Uvea* next the cryſtalline Humour, than in the concave Side of the *Choroides*, upon which the *Retina* is ſpread, and in the *Iris* or anterior Side of the *Uvea*.

§ 3. All Animals, as FABRICIUS *ab Aquapendente* obſerves, have the convex or Back-part of the *Choroides* always covered with more or leſs of this black Pigment; but its concave Side, next the *Retina*, is of different Colours in different Animals. In Swine, and the greateſt Part of Birds and Fiſhes, as well as in Man, the Fore-ſide of the *Choroides* is always black; but in many other Creatures, ſuch as the Lion, Camel, Bear, Ox, Dear, Sheep, Dog, Cat, and many other Quadrupeds, and even in ſome of the Bird kind, that are not endowed with a good Sight, ſuch as the Owl, and other nocturnal Birds, this Tunicle is never black in its Fore-ſide next the *Retina*, but of a ſplended blue, green, yellow, pearl, or other bright Colour. And this I here take Notice of, becauſe ſome of our ſubſequent Reaſonings, about the Manner of Viſion, and the Uſe of the ſeveral Parts of the Eye, will be founded thereon.

§ 4. The *Choroides* is not at all attached to the *Sclerotica*, which it lines internally, but by the Veins, Arteries and Nerves, which piercing the *Sclerotica*, are beſtowed upon it, except at its Edge, where, in going inwards, it forms the *Uvea*. This circular Edge of the *Choroides* ſeems to be of a different Subſtance from the reſt of this Membrane, being much more hard, denſe and white, and therefore is by ſome called the *Ciliary Circle*, becauſe the *Ligamentum Ciliare* ariſes therefrom.

§ 5. Now, the *Choroides*, beſides its membranous Fibres, has a great many others of a quite different Nature, which ariſing from the Circumference of the Entry of the optic Nerve, go obliquely forwards to its Edge, where it forms the Ciliary Circle; at which Place ſome are reflected inwards towards the Edge of the Cryſtalline, and form the muſcular Fibres of the *Ligamentum Ciliare*: Others run forwards upon the Inſide of the *Uvea*, and, like ſo many Rays drawn from the Circumference towards the Centre, terminate in the Edge of the Pupil. Theſe Fibres, by their Contraction, open the Pupil, and enlarge its Hole, when the Light is weak, or when the Object is at a great Diſtance, or obſcurely illuminated, that a greater Number of Rays may enter the Eye; as will afterwards appear.

§ 6. Beſides theſe ſtreight Fibres for opening the Pupil, there are others which embrace it circularly. Theſe are truly muſcular, and being ſpread on the outward Side of the *Uvea*, like a Sphincter, by their Contraction, they leſſen the Pupil, when Objects are too near or luminous, that the Sight may be rendered more diſtinct, and eſpecially that the *Retina* may not be offended by the dazzling Brightneſs of Objects.

That the *Uvea* is furniſhed with ſuch circular Fibres, is now generally agreed by Anatomiſts, tho', I imagine, not ſo much from their being able to demonſtrate them, as from Reaſon and Analogy: For as the Contraction of the Pupil, upon ſtrong Light, is plainly viſible, that Contraction is juſtly preſumed to be owing to ſuch muſcular Fibres; and therefore the famous Mr. RUYSCH, following in this the reaſonable Doctrine of moſt other Anatomiſts, has repreſented this Ring of muſcular Fibres in one or two of his Figures; But he tells us, at the ſame time, *Sculptor hic juſto diſtentius repreſentavit; nam in objecto ipſo non ita luculenter viſuntur.* (*Theſaur. Anatom.* II. *p.* 87.) And, in another Place, he ingeniouſly declares (*ibid.* p. 14.) *Fateor haſce fibras circulares non tam luculenter conſpici poſſe, quin oculi mentis in ſubſidium ſint vocandi.*

This ſame Author contends, that the *Choroides* conſiſts of two different Membranes, each of which hath a diſtinct Net-work of Veſſels, and therefore calls the external Coat *Choroides*, and the internal *Ruyſchiana*. But we ſhall not waſte Time in inquiring whether there be any ſuch Thing as the *Membrana Ruyſchiana* or not; it being of little Conſequence whether it be thought a diſtinct Membrane, or only a Part of the *Choroides.*

§ 7. Moſt of the antient Anatomiſts, ſince the Days of GALEN, have deſcribed the *Uvea* as a convex Membrane. VESALIUS is the only Author I know who has done Juſtice to its Figure, by making it plain; but in this he was not followed by any I know, till Monſ. PETIT, in the *Memoirs of the Acade-*

my of Sciences, *Anno* 1728, demonſtrated it to be truly of that Figure.

What may have led ſo many famous Authors into this Miſtake, ſeems to be the Convexity which it really has in Cows, Sheep, and ſome other Creatures they may have diſſected, joined to the convex Appearance it makes in Man, when his Eyes are looked to. But in Man, it is always plain; and Monſ. PETIT has ſhewed, that, tho' this Membrane be plain, it muſt be ſeen convex, by Reaſon of the Refractions which the viſual Rays ſuffer in paſſing thro' the *Cornea* and aqueous Humour; and, to confirm this by Experiment, he cauſed make a little Machine, ſimilar to the anterior Part of the Eye, and, according as this Machine was full of Water, or empty, one could ſee that the ſame plain Surface, which was in place of the *Uvea*, appeared either convex or plain; which is an experimental Proof, that it is the aqueous Humour that cauſes this convex Appearance of the *Uvea* in the human Eye; and thoſe that have any Knowledge in Optics, will eaſily ſee the Reaſon of it.

§ 8. The learned RIOLAN (*Anthropograph. lib.* iv. *cap.* 4.) has obſerved, that in a Cow's Eye boiled, the *Uvea* can be eaſily ſeparated from the *Choroides*, by being drawn from it with the Point of a Scalpel; from which he concludes, and that not without ſome Appearance of Reaſon, that the *Uvea* is a diſtinct Membrane from the *Choroides*, and only contiguous to it. The ſame Author alſo affirms, that the like Separation may be made in in the human Eye, tho' not ſo eaſily. But in this, I imagine, he is miſtaken; for, with PLEMPIUS, and ſeveral others, this Separation could not be made to ſucceed.

§ 9. This Coat has Nerves, Arteries and Veins from thoſe of the *Sclerotica*, which, as we have before obſerved, pierce it in a great many Places, and are diſtributed thro' all this Membrane. Of theſe Arteries and Veins a great many Branches alſo pierce this Membrane itſelf, and are diſtributed to the *Retina*, *Ligamentum Ciliare*, and the Membranes covering the cryſtalline and vitreous Humours. Thoſe who deſire a more particular Account of theſe Veſſels, and the beautiful *Plexuſes* formed by them in the *Choroides* and *Uvea*, may conſult the famous RUYSCH, whoſe ſubtile Injections have diſcovered moſt wonderful Ramifications and Net-works in theſe Parts.

§ 10. The Pupil or round Hole with which the *Uvea* is peirced, has no fixed Meaſure, being greater or ſmaller, according as leſs or more Light ſhines upon the Eye.

This any one may try; for, when the Light is ſtrong, or the viſual Object too luminous, we contract the Pupil for intercepting a Part of the Light, which otherwiſe would dazzle and hurt our Eyes; but when our Eyes are in no Danger of being hurt by the Light, and eſpecially if the Light is ſo weak as to make but a faint obſcure Picture on the *Retina,* we enlarge this Aperture, that more Light may enter the Eye for making a ſufficient Impreſſion on this Membrane.

§ 11. This Aperture alſo contracts at the near Approach of any ſmall Object, when we endeavour to view it diſtinctly.

§ 12. The ingenious Dr. WHYTT, in his *Eſſay on the Vital Motions, p.* 134. tells us, That PLEMPIUS was the firſt who obſerved this Motion; but in this I apprehend he is miſtaken; for PLEMPIUS no where aſſumes the Honour of this Diſcovery, and he did not write his *Ophthalmographia,* in which he takes Notice of this Motion, till the year 1632, long before which it had been obſerved by others; and particularly by the learned SCHEINER, who, tho' he was not himſelf the firſt Diſcoverer of it, yet he has demonſtrated this Motion by convincing Experiments, in his *Fundamentum Opticum, lib.* 1. *part.* 2. publiſhed in the year 1619.

§ 13. The Reaſon of this Contraction is, becauſe, when the Object is nearer than the neareſt Limits of diſtinct Viſion, the Rays that come from the ſeveral Points of the Object will not be united in ſo many correſponding Points in the *Retina*, but at ſome Place behind it, whence the Picture on the *Retina*, and the Viſion thereby cauſed, will be confuſed and indiſtinct; ſtill the more confuſed, the nearer the Object is to the Eye; but, by the Contraction of the Pupil, the little luminous Pencils, which have for their *Apex* a Point in the Object, and for their Baſis the Aperture of the Pupil, will, by reaſon of their Acuteneſs, proceeding from the Contraction of the Pupil, take up a ſmaller Space on the *Retina*; ſtill the ſmaller, the more the Pupil is contracted; by which means the Confuſion in the Picture will become leſs, and the Sight will be made more diſtinct, tho' leſs clear. This therefore is a good Reaſon for contracting the Pupil, when Objects are nearer than the neareſt Limits of diſtinct Viſion; for they are thereby rendered more diſtinct, and at that Diſtance, they are ſufficiently luminous to be clearly enough ſeen, tho' the Pupil be a little contracted.

But the Pupil may alſo contract in viewing Objects a little more remote than theſe neareſt Limits; for, tho' the Eye can adapt itſelf to that Diſtance, yet, if the Object is large and uncompounded, or if the Parts it conſiſts of, and to which the Eye is attentive, are not too ſmall, there will be no Need of accommodating the Eye exactly to its Diſtance,

ſtance, a leſſer and leſs laborious Contraction of the *Ligamentum Ciliare* may ſuffice to ſhow the Object with ſufficient Diſtinctneſs, eſpecially when the Pupil is contracted at the ſame time; and therefore the Pupil may have good Reaſon to contract, even when Objects are within the Limits of diſtinct Viſion, for rendering the Sight more diſtinct, and at the ſame time, for avoiding that painful and more laborious Contraction of the Ciliary Ligament, which would be neceſſary to ſee the Object with ſufficient Diſtinctneſs, and which, by being on the Strain, would be very fatiguing, when the Object is viewed for any time together.

§ 14. But if the Object is not ſufficiently luminous, this Ligament will not be eaſed of any Part of this Labour, in making the Object appear diſtinct by the Contraction of the Pupil; for, in this Caſe, the Pupil will rather be enlarged for letting in more Light, that the Object may be ſeen with ſufficient Brightneſs. And this is the Reaſon why Objects at a Diſtance, and beyond the furtheſt Limits of diſtinct Viſion, are ſeldom made more diſtinct by the Contraction of the Pupil; for the Light being commonly weak in diſtant Objects, the Pupil is ſo far from contracting, that there is often a Neceſſity that it be dilated, to take in more Light, that the Object may mayappear ſufficiently bright and luminous; yet when the Object is very bright, the Pupil will contract, for rendering the Sight more diſtinct, at whatever Diſtance the Object be from the Eye; for then that Contraction anſwers two Purpoſes; one to exclude an over-great Quantity of Light, which would be offenſive to the Eye, the other to leſſen the Indiſtinctneſs.

§ 15. In Children, this Aperture is uſually more dilated than in grown Perſons.

This may be eaſily ſeen; for, in grown Perſons, the Diameter of the Pupil ſeldom appears equal to the Breadth of the Ring of the *Uvea* on either Side of it; that is, is ſeldom equal to one third of the Breadth of the *Cornea* or *Iris*, and is often much leſs, eſpecially in a good Light. But in Children, the Diameter of the Pupil ſcarce ever appears ſo little as one third of the Breadth of the *Cornea*, and often exceeds Half that Breadth.

Suppoſing then the Diameter of a Child's Pupil, in its relaxed State, when the Light is weak, to be Half the Breadth of the *Iris* or 2 ½ Lines; and ſuppoſing the orbicular Fibres, in their contracted State, to become a third ſhorter than when relaxed (which is the Degree of Contraction that is commonly allowed to Muſcles), this Pupil, in a ſtrong Light, will be contracted to one Line and two thirds, which being a third of the Breadth of the *Cornea*, is nearly what it appears to be at a Medium, from ſuch rude Obſervations as I have had occaſion to make. In like Manner, ſuppoſing the Diameter of the Pupil of grown Perſons, in its relaxed State, to be one third of the Breadth of the *Cornea* or *Iris*, or one Line and two thirds; in its contracted State, it will be one Line and one ninth Part; which alſo ſeems to be pretty near the Truth. But it is not eaſy to determine this exactly; eſpecially that the Magnitude of this Aperture is ſo different, in different Perſons of the ſame Age, and in the ſame Degree of Light.

§ 16. In elderly Perſons, the Pupil is yet ſmaller than in Adults, being ſeldom greater than the Half of the Breadth of the Ring of the *Uvea* ſurrounding it, and conſequently is only about one fifth of the Diameter of the *Iris*; that is, is only about one Line in Diameter: And in ſuch Perſons it has but very little Motion; whence thoſe that begin to want Spectacles, are obliged to hold the Candle between the Eye and the Paper they read, that the ſtrong Light of the Candle may force their rigid Pupils into ſuch a Contraction, as may enable them to ſee more diſtinctly; for in a ſtrong Light the Pupil contracts more forcibly, and to a greater Degree, than it can be made to do by the Senſation of Confuſion only; conſequently it is a Miſtake to think, that, upon ſeeing an Object confuſedly, the Pupil does always contract itſelf to the leaſt Size it is capable of: The Degree to which the Pupil contracts, does in ſome Meaſure indeed depend upon the Senſation of Confuſion in the Object; but it depends yet more upon the Degree of Light, as may eaſily be proved in the following Manner:

§ 17. By Day-light, take a Book, and ſtanding about the Middle of a Room, with your Back to the Window, hold the Book ſo near, that the Letters may appear indiſtinct, and yet not ſo much but that you can read, tho' with ſome Difficulty; then turn your Face to the Light, and the Book will be read with more Eaſe.

Again, holding the Book at the ſame Diſtance from your Eye, go into the darkeſt Part of the Room, and ſtanding with your Back to the Light, you will find the Book not at all legible; but, upon coming to the Window, with your Face to the Light, you will be able to read, eſpecially if the Sun ſhines, with great Eaſe and Diſtinctneſs.

Alſo a Perſon who has been obliged for ſome Years to uſe Spectacles in reading, will, in the Sun-ſhine, be able to read very eaſily without them.

From theſe, and ſuch like Experiments, it appears, that the Contraction of the Pupil depends more upon the Strength of the Light, than upon the Senſation of Confuſion in the Object. And this is the Reaſon why ſuch as begin to need Spectacles, hold the Candle between the Eye and the Paper they read, for cauſing the Pupil to contract, that they may ſee it more diſtinctly; and their holding the Candle in this Manner, is a certain Sign that they begin to want Spectacles.

§ 18. If it ſhould here be aſked, why the Pupil is ſo large in Children, and grows ſmaller and ſmaller continually, as they advance in Years, ſo as in old Age to be ſo very ſmall as it is?

To this I anſwer, That, in Children, the Eyes are full and plump, from a plentiful Supply of all the Humours that diſtend the Globe, by which Means the circular Edge of the *Uvea*, where it is joined to the other Coats of the Eye, muſt be kept at a conſiderable Diſtance from its Centre, and conſequently the Pupil muſt be extended and drawn out to a conſiderable Bigneſs; and the natural State of the Pupil being a State of Dilatation, the Pupil muſt on that Account remain in this dilated State, unleſs when the Mind interpoſes, and wills it to contract, when the

Light is too ſtrong, or when the Pictures are not diſtinct upon the *Retina.*

This Largeneſs of the Pupil in Children is therefore to be conſidered as natural to it, and ariſing from the Make and Plenitude of their Eyes; and tho' it had been the one Half ſmaller than it is, it would ſtill have been eſteemed large, becauſe larger than afterwards in a more advanced Age; for nothing is great or ſmall in itſelf abſolutely conſidered, but only relatively to ſomething elſe with which it is compared.

This whole Queſtion therefore reſolves into this, Why the Pupil grows ſmaller and ſmaller continually as we advance in Years? The Anſwer to which is eaſy:

For, as we Advance in years, the Pupil muſt gradually diminiſh, from the Decay that happens in the Humours of the Eye, and eſpecially in the Aqueous, which always decays the moſt; for that theſe Humours gradually decay, ſeems evident from the Smallneſs and Sinking of the Eyes of elderly Perſons; and that the aqueous Humour decays the moſt, ſeems evident, not only from the Flatneſs and Schriveling of the *Cornea* in ſuch Perſons, but alſo from the *preſbytical* or Long-ſight, that always increaſes as we increaſe in years, inſomuch that in old Age we cannot read at all at an ordinary Diſtance, without the Aſſiſtance of Glaſſes, to ſupply the Defect of Convexity in the *Cornea*, by increaſing the Refraction; for it is a Miſtake to think, that an uniform Sinking in all the Coats and Humours of the Eye, can render the Eye preſbytical: This would have a quite contrary Effect, and the Eye, in place of becoming preſbytical, would become ſhort-ſighted, as in Children, whoſe Eyes are ſmaller than thoſe of Men; for the leaſt Diſtance any Eye can ſee diſtinctly at, is in a Certain fixed Proportion to its Length, or the Diſtance of the *Retina* from the refracting Humours; and therefore this preſbytical Sight argues a Flatneſs in the Eye, ariſing from a Penury of the aqueous Humour.

Now, from this Decay and Scarcity of all the Humours of the Eye, the Eye muſt neceſſarily contract, and become leſs and leſs by Degrees; by which means the outward Edge of the *Uvea* will be brought nearer to its Centre, and conſequently the Pupil will become narrower.

But this Narrowneſs of the Pupil will be yet more increaſed, by the greater Decay that is in the aqueous Humour; for the Tunicles of the Eye, at the Edge of the *Choroides*, where it joins the *Uvea*, for Want of a ſufficient Preſſure from within at that Place, proceeding from the Penury and Decay of the aqueous Humour, will be made to fall inwards towards the *Axis* of the Eye, by which the *Uvea* will become narrower, and the Pupil will be reduced to a leſs Size, than what would have happened had the whole Eye contracted uniformly over all.

§ 19. This Theory is greatly confirmed from what may be obſerved as to the State of the Pupil in the *Exophthalmia* and *Microphthalmia.*

In the *Exophthalmia,* which conſiſts in the immoderate Fullneſs and Diſtention of the Globe, the Pupil is always greatly dilated; whereas, on the contrary, in the *Microphthalmia,* or Atrophy of the Eye, from whatever Cauſe it may have proceeded, the Pupil is always found contracted; which Contraction can proceed from nothing but a Penury of the Humours of the Eye, and eſpecially of the Aqueous; for it is alſo to be obſerved, that when the aqueous Humour is loſt or diminiſhed, by a Wound made in the *Cornea,* the Pupil preſently Contracts, and has its Size leſſened, tho' the other Humours remain as they were before. This was taken notice of by GALEN (*de Symptom. Cauſ. lib.* 1.) who therefore, with great Reaſon, attributes the Corrugation of the *Cornea* of old Men, when it is accompanied with a Contraction of the Pupil, to a Scarcity of the aqueous Humour;

mour; whereas, when the Pupil continues of a natural Size, he aſcribes the Symptom to the *Cornea* itſelf. But of this more hereafter.

§ 20. But there is yet another Reaſon why the Pupil becomes ſmaller, as we advance in Years, and that is, its frequent Contraction, in order to ſee near Objects with ſufficient Diſtinctneſs.

For, when the Sight is perfect, that is, when it is neither two ſtrong nor two weak, and more eſpecially when the Sight is preſbytical or weak, all Objects that are very near the Eyes will appear confuſed and indiſtinct: To remedy which Confuſion, the Pupil contracts, and, by contracting, becomes ſmaller and ſmaller continually; for, by its frequent Contractions, to ſee near Objects more diſtinctly, the orbicular Fibres ſhrink and become ſhorter, by which means the Pupil becomes narrower; juſt as the Fingers of Work-people are much bended, by the frequent Contractions of the *Flexores Digitorum*.

It is therefore no Wonder, that the Pupil, which in Children is large, ſhould gradually become narrower and more contracted as they advance in Age; for, as they advance in Age, the Sight becomes more and more preſbytical, which muſt occaſion the Pupil to contract more and more, for to ſee near Objects diſtinctly.

ſtinctly. Whence we may ſee, why the Pupil, which in Children is large, always continues pretty much ſo in thoſe who are Short-ſighted; for in them near Objects appear diſtinct, and therefore they are not obliged to contract the Pupil for ſeeing ſuch Objects more diſtinctly; and tho' diſtant Objects appear confuſed, yet the Pupil ſeldom contracts for ſeeing them more diſtinctly; becauſe, when the Object is at a Diſtance, it ſends leſs Light into the Eye than what is neceſſary for ſeeing clearly, unleſs when the Pupil is dilated.

§ 21. But there is yet a third Reaſon why the Pupil becomes ſmaller as we advance in Years, and that is, the different States and Conditions of the *Cornea* in the different Stages of Life.

In Children, the *Cornea* is extremely flexible and yielding, ſo as to be very eaſily bent into a more convex Figure, when the Cryſtalline is moved forwards for ſeeing near Objects more diſtinctly; and the *Cornea* being thus bent, the Cryſtalline will not need to be brought ſo much forwards, as it behoved to have been for diſtinct Viſion, had the *Cornea* been more ſtiff and unflexible. Children will therefore ſee near Objects diſtinctly with a ſmall and eaſy Motion of the Cryſtalline, and will have little occaſion to contract their Pupil for rendering their Sight diſtinct. But in grown Perſons, the *Cornea* is ſomewhat ſtiffer, and does not ſo eaſily bend; whence the Cryſtalline will need to be moved more forwards, by a greater and more laborious Contraction of the Ciliary Proceſs; to avoid which they will have frequent occaſion to contract the Pupil for to enable them to ſee near Objects more diſtinctly. And in elderly Perſons this Contraction of the Pupil will be yet more neceſſary for ſeeing more diſtinctly at a ſmall Diſtance; for in them the Eye is not only flatter, but the *Cornea* being more rigid, is incapable of bending into a more convex Figure. And this is the Reaſon why they can hardly read without Spectacles, unleſs the Print be very large, or the Light very ſtrong, ſo as to cauſe a great Contraction of the Pupil; for, as has been already noticed, in a ſtrong Light the Pupil contracts more forcibly, and to a greater Degree, than it can be made to do by the Senſation of Confuſion only; and it is for this Reaſon, that elderly Perſons are obliged to hold the Candle between the Eye and the Paper they read; and their doing ſo, is a certain Sign they begin to want Spectacles. But all this will be better underſtood from what is to follow concerning the Manner of Viſion, and the Uſe of the ſeveral Parts of the Eye concerned therein, which I ſhall not now anticipate.

§ 22. The ingenious Dr. WHYTT, in his *Eſſay on the Vital Motions* (*Page* 138.) has given us a different Solution of this *Phænomenon*, which, tho' it be ſuch as I cannot think ſatisfactory, yet the Regard I have for the learned Author will not allow me to paſs it by without noticing it.

He ſays, " In Infants, but more eſpecially " in ſuch as are newly born, the Pupil is " conſiderably wider than in grown People, " where the Eyes of both are expoſed to " the ſame Degree of Light; 1. Becauſe in " *Fœtuſes*, and new born Children, the *Cornea* " being thicker, leſs tranſparent, flatter, and " not ſufficiently ſtretched, on account of " the ſmall Quantity of the aqueous Humour, " Viſion is very indiſtinct, and the *Retina* " is leſs affected by the Rays of Light, which " are neither freely tranſmitted to, nor pro" perly collected upon it."

But, ſurely, if Viſion is very indiſtinct in ſuch Children, the Pupil ought to contract, to diminiſh the Indiſtinctneſs; for, by ſuch a Contraction, the Indiſtinctneſs is always leſſened, whether this Indiſtinctneſs proceeds from the Object's being too near or too far off for diſtinct Viſion, or, which is the ſame Thing, whether the Eye be too flat or too convex. This the Doctor ſeems not to have adverted to, elſe he would not have affirmed (*p.* 135.) “ When we look at remote Objects, “ the Pupil becomes wider, chiefly becauſe the “ Contraction of its Sphincter Muſcle is no “ longer neceſſary to leſſen the Diſſipation “ of the Rays.” The contrary of which is ſo evident, that the Doctor himſelf, on Reflection, will no doubt readily acknowledge it; and therefore the Pupil of young Children ought to contract, to diminiſh the Indiſtinctneſs; and tho’ in ſuch Children leſs Light ſhould be tranſmitted to the *Retina*, on account of the ſuppoſed Thickneſs and Want of Tranſparency in the *Cornea*, yet, according to this Gentleman’s Principles, this ought not to hinder the Pupil from contracting; for, in the ſame Page, he maintains, “ That “ the Contraction of the Pupil is principally “ owing to a voluntary Exertion of the “ Mind’s Power in order to render Viſion “ more diſtinct, but, in a very ſmall “ Degree, to the ſtronger and more vivid “ Light which the Object reflects upon the “ Eye; ” and, in conſequence of this Principle, he, without Ceremony, and, in my Apprehenſion, ſomewhat raſhly, accuſes the juſtly famous and truly learned Dr. JURIN of a Miſtake in ſaying, “ That in a faint “ Light the Pupil is ſo far from contracting

“ in order to diſtinct Viſion, that there is “ rather a Neceſſity of dilating it in order “ to take in more Light.” (See the fore-mentioned *Eſſay*, *p.* 134.) But, in my Apprehenſion, this Gentleman himſelf is the Perſon that is guilty of the Miſtake, and not Dr. JURIN; for the Doctor has proved, by unexceptionable Experiments, that in a ſtrong Light the Pupil contracts to a greater Degree than it can be made to do by the Senſation of Confuſion only; and that upon ſeeing an Object confuſedly, it does not always contract itſelf to the leaſt Size it is capable of. (See his excellent *Eſſay upon diſtinct and indiſtinct Viſion*, *par.* 148.)

If it ſhould be ſaid, that in Children the Pupil is dilated, becauſe leſs Light enters their Eyes on account of the Opacity of the *Cornea*, and that the Indiſtinctneſs of Sight, ariſing from the Flatneſs of the *Cornea*, is not ſufficient to prevent this Dilatation; I readily acknowledge, that the Reaſoning is juſt, tho’ contrary to our Author’s Principles. But, as Children are obſerved to ſee at leaſt as clearly as afterwards when grown up, and much more ſo than elderly Perſons, this Reaſoning will not ſolve the Problem in queſtion, becauſe built on an Error in Fact.

2. Another Reaſon brought by this learned Gentleman is, " becauſe Children want in a " great Meaſure the Faculty of contracting " the Pupil in order to the more diſtinct " Viſion of near Objects, which (ſays he) " ſeems to be partly acquired by Habit."

But, as I know no Reaſon for thinking that Childrenare deprived of any Part of this Power, or that they acquire it afterwards by Habit, I cannot reſt this *Phænomenon* on ſo improbable a Foundation. We ſee Children open and ſhut their Eyes, ſwallow down their Food, and move all their Limbs with as much Agility and Eaſe as afterwards. We ſee they can bend their Body a good way back, and can bring their Toes to their Mouth, neither of which they can do ſo eaſily after that they are grown up; and the Muſcles of Reſpiration, as well as thoſe of Deglutition, perform their Office from the Birth, as well as at the Age of fifty; and therefore it may reaſonably be preſumed, that Children can, from the Beginning, contract their Pupils, and that this Dilatation of the Pupil does not proceed from any want of Power in them to contract it. And to infer that Children want Power to contract the Pupil, becauſe in them it is found dilated, is to argue in a Circle: It is to conclude, that the Pupil is large in Children, becauſe they want the Power of contracting it; and that they have not the Power of contracting it, becauſe in them it is always large and dilated; which way of Reaſoning will not ſatisfy.

I might here add further, that it is not only a reaſonable Preſumption, that Children from the Beginning are poſſeſſed of a Power of contracting their Pupils, but it has alſo been handed down to us as an eſtabliſhed Fact by the moſt unexceptionable Authors. *De la* HIRE himſelf, in the firſt Page of his Diſſertation, *ſur le differens Accidens de la Vüe*, tells us this in the following Words: *Les Enfens a cauſe que leurs muſcles et leurs tendons ſont encore fort mous, peuvent avec facilité dilater beaucoup l' ouverture de la prunelle dans l' obſcurité, et au contraire la reſſerrer extremement dans la grand lumiere, &c.*

But our Author goes on, and adds, that "in old People the Pupil becomes leſs move-"able, becauſe the *Retina* grows leſs ſenſible "of the *Stimulus* of Light, and the muſcular "Fibres of the *Iris* loſe in part their contractile "Power. Further, in old Age, the *Cornea*, "on account of the decreaſe of the aqueous "Humour, not only loſes its Brilliancy, but "becomes alſo in ſome Degree wrinkled; "whence the *Retina* will be leſs affected by "Light, and conſequently the Pupil will be "leſs contracted." So far this ingenious Gentleman.

But if, in old Age, the *Retina* grows leſs ſenſible of Light (as will readily be acknowledged) the Pupil, in place of being contracted, ought to dilate itſelf, to take in more Light, "eſpeci-" ally that (as our Author informs us) the muſ-" cular Fibres of the *Iris*, (by which the Pupil " is contracted) have in part loſt their con-" tractile Power:" For our Author acknowledges, that " the natural State of the Pupil " is that of Dilation, and that the longitudinal " Fibres of the *Iris* being much more con-" ſpicuous and ſtronger than the circular Plan, " muſt, by their natural Contraction, keep the " Pupil always dilated, unleſs the latter are " excited into Action by ſome particular " Cauſe." To me therefore it appears, that the Inſenſibility of the *Retina*, and the Weakneſs of the contractile Power of the muſcular Fibres of the *Iris*, are ſo far from having any hand in that Contraction of the Pupil, which gradually increaſes as we increaſe in years, that they ought rather to occaſion a gradual Dilatation of it.

And the ſame thing may be ſaid of that " Wrinkling and want of Brilliancy (as he " calls it) in the *Cornea*, by which the *Retina* " becomes leſs affected by Light:" For the leſs the *Retina* ſuffers by Light, the Pupil ought to dilate itſelf the more; as he himſelf acknowledges, when he accounts for the Wideneſs of the Pupil in young Children, from an Opacity and Thickneſs of the *Cornea*, thro' which the Light not being freely tranſmitted, the *Retina* is leſs affected by it.

There ſeems therefore to be nothing in this whole Paragraph which I have laſt quoted that can any way aſſiſt us in accounting for the Wideneſs of the Pupil in Children and its gradual Contraction as they advance in years: All that can reaſonably be deduced from it, when properly explained, ſeems to be, that as we grow older, the Pupil ought gradually to become wider and leſs moveable; which, however, is far from being the Caſe; for it always grows narrower and more contracted.

§ 23. There is alſo a great Variety in the Magnitude of the Pupil in Perſons of the ſame Age. In the *Myopes*, or thoſe who are Short-ſighted, it is commonly very large; whereas, in thoſe whoſe Sight is perfect, and more eſpecially in the preſbytical or weak Sight, it is much ſmaller.

Several plauſible Hypotheſes have been invented by Men of Learning and Ingenuity for explaining this *Phænomenon*. But, to ſave time, I ſhall not now examine them. What to me appears moſt probable, may be gathered from what has been already ſaid; for when the Sight is perfect, and more eſpecially when it is weak or preſbytical, the Pupil will have frequent occaſion to contract for ſeeing near Objects more dictinctly: But, by theſe repeated Contractions, the orbicular Fibres muſt ſhrink and become ſhorter, by which Means the Pupil will be made narrower; juſt as the Fingers of Work-people become bended by the frequent Contractions of the *Flexores Digitorum*. But in thoſe who are Short-ſighted, this will not happen; for in them near Objects appear diſtinct, and therefore not having occaſion to contract the Pupil for ſeeing ſuch Objects more diſtinctly, the Pupil will continue large, much as when they were Children; for, tho' diſtant Objects appear confuſed to ſuch as are Short-ſighted, yet the Pupil ſeldom contracts for ſeeing them diſtinctly; becauſe, when the Object is at a Diſtance, the Faintneſs of the Light cauſes the Pupil to keep dilated for taking in more Light, that the Sight may be ſufficiently ſtrong and lively.

§ 24. But there is yet another Reaſon for this Largeneſs of the Pupil in myopical Eyes: For underſtanding which, it muſt be obſerved, that in the preſbytical or weak Sight, as well as in that which is perfect, the Eye is more ſenſibly affected, and ſuffers more by great Light, than when the Sight is myopical, with the ſame Opening of the Pupil; for the luminous Bodies that ſurround us, and which are not very near us, ſend Rays into the Eye, which, in the *Viſus perfectus*, are brought together, and united upon the *Retina*, and make but a very ſmall Baſe in the preſbytical Eye, whence the Impreſſion made on the *Retina* will be ſtrong and lively in both theſe Eyes, and muſt therein cauſe ſome Pain and Uneaſineſs. But this will not happen ſo much in the myopical Sight, becauſe theſe ſame Rays make a larger Baſe on the *Retina*; for all other Things being equal, the myopical Eye always ſees Objects more confuſedly than does either the perfect or preſbytical Eye: And this Confuſion is cauſed by the Space which the Rays that come from each Point of the Object occupy on the Fund of the Eye. This therefore is a good Reaſon why the Pupil, which in Children is very large, continues more ſo in thoſe who are Short-ſighted, than in thoſe whoſe Sight is either perfect or weak, and who, by reaſon of the too ſtrong Impreſſion made upon the *Retina* by bright and luminous Objects, are obliged to contract the Pupil for keeping out a Part of the Light; whence the Pupil becomes gradually narrower.

§ 25. The Pupil is alſo large in ſuch as have black Eyes, and are of a dark black Complexion; and on the contrary, in thoſe who are very fair, and have Light-blue Eyes, it is commonly a good deal ſmaller.

This was obſerved by AETIUS, and after him by many others, who therefore imagined that Black-ey'd People were moſt liable to that preternatural Dilatation of the Pupil, which the *Greeks* called *Mydriaſis* and *Platycoria.* But why the Pupil ſhould thus vary with the Complexion and Colour of the Eyes, none of them have been able to explain.

The Reaſon ſeems to be this: When the Eye-laſhes are black, the Eyes are better ſhaded from the Light, and little Light will be reflected from their inner Side upon the Eye; and therefore the Pupil, which always dilates itſelf when the Light is faint, will keep wider than in thoſe who, being of a fair Complexion, have their Eye-laſhes white; for white Eye-laſhes, by reflecting the Light copiouſly into the Eye, muſt make the Pupil contract, and become narrower. And this is the Reaſon why the Pupil is ſmall in ſuch as are fair and have light-blue Eyes.

§ 26. From this Reflexion of the Light into the Eyes of fair People, they ſee worſe in bright Day-light than towards Night; as was obſerved by ARISTOTLE, and after him by many others both Phyſicians and Philoſophers.

I know that PLEMPIUS denies this, upon the Authority of ſome of his Friends who were very fair. But I ſuſpect there has been ſome Miſtake in it; for having had occaſion lately to be with a Gentleman of this Complexion, he owned to me that he ſaw beſt towards Night, and could read much better than moſt others in a faint weak Light, tho', as he aſſured me, he was not Short-ſighted. And the ſame thing is confirmed by that memorable Story which MONALTUS tells us of one he knew, who, being very fair, ſaw ill in bright Day-light but better towards Night: But, as he advanced in years, his Eye-laſhes becoming leſs white, this Difference in his Sight by day and by night gradually diminiſhed, and came nearer to what is common and natural. This Man being taken by the Turks, they dyed his Eye-laſhes Black, by which his Sight was greatly mended: But it returned to what it was before, when the black Colour was waſhed off. All this I have accounted for from the Colour of the Eye-laſhes, towards the Beginning of this Treatiſe; to which therefore the Reader, if he pleaſes, may have Recourſe.

§ 27. In Hollow-eyed People, or ſuch as have their Eyes ſet deep in the Socket, the Pupil muſt alſo be large; and, on the contrary, when the Eyes are prominent, and advance forward to the Edge of the Orbit, or beyond it, it muſt be much ſmaller.

This I do not find has been taken notice of by Authors. But it is an obvious Conſequence that muſt follow from the Situation of the Eye; for when the Eye is ſunk in the Socket, it is more ſhaded from the Light that comes from Objects at a Diſtance from the *Axis* of Viſion, and towards which the Eye is not directed; and being thus ſhaded, leſs Light will enter the Eye, and conſequently the Pupil will dilate itſelf, and, by dilating, will become wider; whereas, when the Eye is prominent, it will receive Light, not only from the Object in view, but alſo from all the Objects round about it; for none of the Light being intercepted by the Orbit, it will all fall upon the Eye; whence the Pupil muſt contract and conſequently muſt become narrower.

§ 28. It is from this ſhading of the Eyes in Hollow-eyed People, and the Dilatation of the Pupil thence ariſing, that they ſee ſo much better than others, and eſpecially than thoſe whoſe Eyes are prominent.

For ſince the Eye always ſees beſt from among Darkneſs, not only on account of the Dilatation of the Pupil, but alſo becauſe the Picture on the *Retina* is not mixed with foreign Light which does not belong to the

Object in view; I ſay, ſince the Eye ſees beſt from among Darkneſs, it muſt alſo, for the ſame Reaſon, ſee beſt when ſet deep in the Socket; for the Socket, by ſhading the Eye, muſt have an Effect ſimilar to that of a long Tube, thro' which, when applied to the Eye, the Stars may be ſeen in the Day-time, when to the naked Eye they are quite inviſible: Whence PLEMPIUS tells us, that he knew ſeveral Hollow-eyed People, who lying on their Back upon the Ground, and looking to the Heavens, could, in Day-light, ſee the Stars, as well as from the Bottom of a Pit, or as thro' a long Tube applied to the Eye, (*Ophthalmograph. lib.* iv. *probl.* 1.) But thoſe who have prominent Eyes do not ſee ſo well: But they have a Remedy at hand, whereby their Sight may be much improved; and that is, to apply their folded Hand to their Eye, thro' which they will ſee as well as thoſe who are naturally Hollow-eyed.

§ 29. There is alſo a great Diverſity with regard to the Magnitude of the Pupil, according to the different States and Conditions of the Coats and Humours of the Eye, and of the *Retina* on which the Rays are made to converge.

To explain this fully, would engage us too far in Practice, and oblige us to explain ſeveral Diſeaſes of the Eye, ſome of which have not as yet been rightly explained by the Generality of Authors. But as this does not ſo properly belong to the Subject before us, and would take up a good deal of Time, I ſhall here only obſerve, that, when the Humours are impure and muddy, the Pupil is always large, becauſe leſs Light is tranſmitted to the *Retina*: It is alſo large, when the *Retina*, from any Obſtruction or Preſſure upon the Nerve, has become leſs ſenſible of the Impreſſion made upon it by the Light. And this is the Reaſon why the Pupil is ſo very large in the *Amauroſis* or *Gutta Serena*, in which the *Retina* is quite inſenſible, by reaſon of a total Obſtruction and *Paralyſis* in the Nerve.

§ 30. MAITRE-JEAN indeed affirms, that, in this Diſeaſe, the Pupil is no larger than what it is uſually, when we view Objects at a moderate Diſtance, (*Malad. de l' Oeil, p.* 278.) But this is contrary to what others teach, and to what I myſelf have had frequent occaſion to obſerve; for, in the *Amauroſis*, the Pupil is always large, unleſs when complicated with ſome other Diſeaſe which makes it narrow; for the natural State of the Pupil being a State of Dilatation, when the Eye is inſenſible of the Light, there is nothing that can hinder the Pupil from aſſuming that State of Dilatation which is natural to it.

It is indeed true, that, when one of the Eyes is only affected with this Diſeaſe, the Pupil of that Eye will dilate or contract according as the other Eye is ſhut or open, or as leſs or more Light ſhines upon it; for, having been accuſtomed to move both Pupils together, a habitual or cuſtomary Connection has grown up between their Motions, which makes the Pupil of the diſeaſed Eye ſympathize with and follow the Motion of the other. And this, I apprehend, is what led MAITRE-JEAN into the Miſtake he has fallen into with regard to the Magnitude of the Pupil in the *Amauroſis*; and that, finding it pretty much contracted when the ſound Eye was open, he concluded, contrary to the Opinion commonly received, that in this Diſeaſe it is not larger than what it is naturally, when we view Objects at a moderate Diſtance.

§ 31. It is from this Muddineſs and Want of Tranſparency in the Humours of the Eye, and from a beginning Obſtruction of the optic Nerve, by which the Senſibility of the *Retina* is impaired, that the *Mydriaſis* moſt commonly proceeds; for, ſo far as I have been able to obſerve, neither the *Mydriaſis*, nor its oppoſite, the *Myoſis* or *Phthiſis Pupillæ*, are properly Diſeaſes of the Eye, but only Symptoms ariſing from ſome other Diſeaſe or Defect in this Organ; whence we may ſee, why ſome

Authors have defined the *Mydriaſis* to be *an Alteration of the viſive Faculty from turbid Humours*, and why others have told us, that, *when the Dilatation is neglected, it ends in a Suffuſion or Cataract*; From this alſo we may ſee the Miſtake which a great many Authors have fallen into, in aſcribing all thoſe Defects of Sight which they ſee accompanying the *Mydriaſis* and *Myoſis*, to the Dilatation and Contraction of the Pupil; for few or none of theſe Defects ariſe from any ſuch Cauſe, but from that other Diſeaſe or Defect of the Eye from which that Dilatation and Contraction itſelf proceeds.

§ 32. In different Animals, the Pupils are of different Forms, according to their peculiar Occaſions, and the Uſe they make of them both by day and night. In the Dog, Ape, and many other Quadrupeds, as alſo in Birds of all Kinds, and the greateſt Part of Fiſhes, the Pupil is circular, as in Man; by which they are enabled to ſee equally well above and below, and on both Sides: But in Cows, Goats, Horſes, Sheep, and divers other Creatures, this Aperture is oblong or elliptical, its greateſt Diameter lying tranſverſely towards the Angles of the Eye. In Cats, it is neither round nor elliptical, but in Form of an erect Fiſſure croſſing the Eye-lids perpendicularly. Theſe Differences are not the Effect of blind

Chance, but of that wiſe Counſel and Deſign which Nature always employs in the Formation of all the Parts of Animals, for the beſt Ends and Purpoſes. But this will fall more naturally to be explained afterwards, when we come to account for the Differences in the Conformation of the Eyes of different Creatures.

CHAP. IX.

Of the Retina *and Optic Nerve.*

SECT. I. THE third Membrane of the Eye is the *Retina*, concerning which I have nothing I need to remark but what has been before taken Notice of in the general Idea of the Eye, which we ſhall not now repeat; but ſhall rather make ſome Obſervations on the optic Nerve, of whoſe medullary Subſtance it is an Expanſion.

The optic Nerves ariſe from thoſe Protuberances in the Brain, of old by GALEN called *Thalami Nervorum Opticorum*; from thence they deſcend towards the Baſis of the Skull, and going forwards, paſs out of it into to the Orbits by a Hole in their Bottom; at which Place they receive a Covering from the *Dura Mater*, and are inſerted into the Back-part of the Globe, tho' not in its *Axis*, as WILLIS and BRIGGS maintain, but a little on the Inſide towards the Noſe.

Theſe Nerves are the largeſt of all the Nerves that ariſe from the Brain: Like all the other Nerves of the Body, they are nothing but a Bundle of very fine ſoft Fibres, which ariſing from the Brain, are covered and tied together with the Membrane which they receive from the *Pia Mater*. MALPIGIUS, in his Epiſtle to FRACASSATUS, has obſerved, that in the Tunny and Sword-fiſh (*Thinnus* and *Xiphias*) theſe Fibres form a Membrane, which being folded up into many equal Plaits, like a Fan, compoſe the optic Nerves of thoſe Animals; whence, when the Coats of the Nerve are removed, by unfolding thoſe Plaits, the Nerve can be expanded out into a thin broad Membrane. This was not a new Diſcovery in MALPIGIUS; for it had been obſerved long before by that great Anatomiſt EUSTACHIUS (*lib. de Axamin. Oſs,*) But this Structure is peculiar to thoſe Fiſhes, and does not take place in Man and other Creatures. ROLFINCIUS indeed unwarily ſays, that this Structure is general, and obtains in the optic Nerves of all Animals without

Exception, (*Diſſert. Anat. lib.* iv. *cap.* 32.) But in this he is refuted by all Anatomiſts; and even MALPIGIUS himſelf informs us, that in Cows, Goats, Swine, *&c.* whoſe Eyes he had boiled a little, that they might be the better obſerved with a Microſcope, he could find no ſuch Foldings, but that the Nerve appeared to be a Bundle of longitudinal Fibres, each of which was covered with a Coat from the *Pia Mater*, and which, when the Nerve was ſqueezed, ſpewed out the ſoft medullary Subſtance which they had from the Brain.

§ 2. GALEN maintains, that the optic Nerves are hollow and pervious, having a Cavity in their Middle, by which they communicate at that Place where they are conjoined. This Cavity, he ſays, was firſt obſerved by HEROPHILUS, whoſe Diligence in anatomical Matters was ſo great, that, according to TERTULLIAN, he diſſected no leſs then ſeven hundred human Bodies.

In this GALEN was followed by a great many Anatomiſts; for, till the Time of VESALIUS, his Authority continued ſo great amongſt them, that few ventured to deny or diſpute any Thing he had affirmed; and the learned PLEMPIUS, tho' he rejects the Doctrine of GALEN, with regard to this Communication betwixt the Nerves, yet agrees with him in making them pervious, and deſcribes the Method by which their Cavities may be found. But, as many later Anatomiſts have not been able to diſcover theſe Cavities, tho' they ſought for them in the Manner recommended by GALEN and PLEMPIUS, I ſcruple not to deny their Exiſtence. I know indeed, that theſe Nerves are ſomewhat ſoft and porous in their Middle, thro' which alſo an Artery runs; which may have impoſed on ſuch as entertained too favourable an Opinion of GALEN, and others who had copied him. But I muſt be forgiven to affirm, that they are never hollow, as GALEN imagined. And in this I have the Authority of CARPUS, VESALIUS, FALLOPIUS, EUSTACHIUS, COITER, COLUMBUS, VELVERDA, AQUAPENDENS, and other celebrated Anatomiſts; none of whom could find any manifeſt Cavity in thoſe, or any of our other Nerves.

§ 3. It is remarkable, that the optic Nerves are always conjoined above the *Cella Turcica:* And this Union is ſo cloſs, that Anatomiſts are not agreed about the Manner of their Conjunction. Some contend, that they croſs one another in this Place, and that the Right-nerve goes to the Left-eye, and the Left-nerve to the Right-eye. What our juſtly eminent Sir ISAAC NEWTON's Opinion was, with regard to this Conjunction, may be ſeen in thoſe beautiful Queries he has annexed to his *Optics*. His Words are, "Are not "the Species of Objects ſeen with both Eyes "united where the optic Nerves meet, before "they come unto the Brain; the Fibres on "the Right-ſide of both Nerves uniting "there, and, after Union, going thence into "the Brain, in the Nerve which is on the "Right-ſide of the Head, and the Fibres on "the Left-ſide of both Nerves uniting in "the ſame Place, and after Union going into "the Brain in the Nerve which is on the Left-"ſide of the Head, and theſe two Nerves "meeting in the Brain, in ſuch a Manner that "their Fibres make but one intire Species or "Picture, Half of which on the Right-ſide "of the *Senſorium* comes from the Right-"ſide of both Eyes, thro' the Right-ſide "of both optic Nerves, to the Place where-"in the Nerves meet, and from thence on "the Right-ſide of the Head into the Brain; "and the other Half, on the Left-ſide of the "*Senſorium*, comes in like manner from the "left Side of both Eyes?"

Others again deny any Interſection or Croſſing in theſe Nerves; but are as much divided amongſt themſelves in the Manner of their Junction; ſome affirming, that they are only united by a cloſs Coheſion, while others maintain, that at this Place of Union, there is a total Mixture and Confuſion of Subſtance; by which Means ſome ſuppoſe, that the two Nerves are made to communicate with one another.

The learned RIOLAN (*Animad. in Bauchin.*) affirms, that our optic Nerves are only conjoined by ſimple Contact, and that only by means of an interjected nervous Tie in form of the Letter H.

§ 4. For my own Part, I never could ſee any ſuch Tie in any human Subject; and tho' it muſt be acknowledged, that our optic Nerves are ſo cloſely conjoined that their Subſtances ſeem to be confounded, yet there are ſeveral Obſervations which plainly prove, that they are united only by a cloſs Coheſion, without any Decuſſation, Interſection, Mixture or Confuſion of Subſtance.

Thus VESALIUS, AQUAPENDENS, VALVERDA and LOSSELIUS, tell us, that they have ſometimes found theſe Nerves ſeparated thro' their whole Courſe from the Brain to the Eyes; whence we may ſafely conclude, that they are always diſtinct, tho' they are commonly united near the *Infundibulum*, by means of the Membranes that cover them.

The ſame VESALIUS has alſo more than once obſerved, that one of the optic Nerves was ſmall and withered, thro' its whole Courſe from the diſeaſed Eye, to which it belonged, to its Origin on the ſame Side of the Brain, whilſt the other Nerve, belonging to the ſound Eye, was quite full and plump, and kept always on the ſame Side with the ſound Eye to which it belonged, (*de Corp. Hum. Fabrica, lib.* iv. *cap.* 4.)

CÆSALPINUS mentions ſuch another Caſe which was ſeen at *Piſa, anno* 1590.

From theſe, and ſuch like Obſervations, it plainly follows, that our optic Nerves do not interſect each other, nor mix and confound their Subſtances, but are only united by a cloſs Coheſion, without any Communication of Pores.

§ 5. If it ſhould be here aſked, For what Ends the optic Nerves are thus conjoined? The Opinion of GALEN on this Head deſerves, in the firſt Place, to be examined.

This learned *Greek* tells us, that this happens on a twofold Account: *Firſt,* That Objects ſeen with both Eyes may not appear double; and this he thinks is the chief Reaſon why our optic Nerves are united; and he glories in the Diſcovery, which, he ſays, is worthy to be aſcribed to ſome of the Gods. (*de Off. Part. lib.* x. *cap.* 14.). In this he has been, and ſtill is followed by a great many learned Men, both Phyſicians and Philoſophers; ſome of whom, to confirm this Opinion, have obſerved, that in Animals that do not look the ſame way with both Eyes, ſuch as the Chamelion, Birds, and Fiſhes, the optic Nerves are not united, but are diſtinct thro' their whole Courſe; whereas, in Animals that look the ſame way with both Eyes, as Men, Sheep, Dogs, Oxen, *&c.* they always meet before they come unto the Brain.

§ 6. Theſe Reaſons, it muſt be acknowledged, are plauſible, and at firſt View ſeem to render this Hypotheſis very probable; and yet, when the Matter ſhall be duly examined, I am confident, little Foundation will be found for any ſuch Opinion. For,

1*ſt*, If this Conjunction were neceſſary, to the end that Objects might appear ſingle, the ſame would alſo be neceſſary in all our other Senſes, and every ſimple Sound would be heard double, becauſe our Ears are double, and our auditory Nerves quite diſtinct. But this is contrary to Experience; every ſimple Sound being heard ſimple as it is, tho' our auditory Nerves are ſo far from being united, that they take a different and almoſt oppoſite Courſe. Whence we conclude, that this ſingle Appearance of Objects does not require that our optic Nerves ſhould be conjoined.

2*dly*, When one of the Eyes is diſtorted, either by a Spaſm in any of its Muſcles, or

from

from its being preſſed aſide by the Finger, ſo as to have its *Axis* turned away from the Object to which the other is directed, all Objects appear double, tho' this Diſtortion does not diſſolve the Union of the Nerves: Whence it follows, that this Union cannot be the Cauſe why Objects are not ſeen double.

3*dly*, It has been juſt now ſhown, from the Obſervations of VESALIUS and CÆSALPINUS, that tho' our optic Nerves coaleſce at the *Cella Turcica*, yet nevertheleſs they keep diſtinct thro' their whole Courſe, without any Interſection, Mixture or Confuſion of Subſtance, or Communication of Pores; and therefore this ſimple Coheſion can contribute nothing towards the ſingle Appearance of Objects.

4*thly*, Tho' this Communication of Pores ſhould be allowed, it could not cauſe the Object to be ſeen ſingle; becauſe theſe Pores are again divided, and proceed in this divided State to the Place of Senſation in the Brain where the Mind or Sentient Principle reſides.

5*thly*, VESALIUS, VALVERDA, AQUAPENDENS and LOSSELIUS, ſometimes found the optic Nerves ſeparated thro' their whole Courſe from the Brain to the Eyes; and yet thoſe Perſons, when in Life, ſaw Objects ſingle as other Men do, which would have been impoſſible,

ble, if this ſingle Appearance had depended on the Conjunction of thoſe Nerves.

6*thly*, As this Conjunction of the optic Nerves can contribute nothing towards the ſingle Appearance of Objects, ſo, on the other hand, this *Phænomenon* admits of an eaſy Solution, without any ſuch Suppoſition; there being nothing more required, but that we be poſſeſſed of a Power of ſeeing Things in the Place where they are: For tho' the Object be ſeen by both Eyes, yet being ſeen in the ſame Place, it muſt appear ſingle; as we can have no Conception of the Penetration of Matter, or that two Things individually the ſame can exiſt in the ſame Place at the ſame Time; and that we are poſſeſſed of a Power of ſeeing Objects in the Place where they are, is Matter of Experience; the Reaſon of which ſhall be explained afterwards in its proper Place.

In the mean time, from this we may ſee whence it comes to paſs, that when the Pictures of two or two hundred ſimilar Objects, either of the ſame or of different Colours, are, by Means of as many convex *Lenſes*, caſt from a Board upon a Wall, or a Sheet of white Paper in a dark Room, ſo as all the Pictures may coincide and fall on the ſame Place of the Paper, all theſe Pictures ſhall appear but one, tho' there be really as many of them painted on the Paper as there are Objects without. If theſe Objects are all of one Colour, this Picture will alſo be ſeen of the ſame Colour; if they are of different Colours, it will appear of that Colour which reſults from the Mixture of all the different Colours of the Objects. But whether they be of the ſame or different Colours, their Pictures will always appear ſingle, becauſe ſeen in the ſame Place.

And of the ſame Kind with this Experiment, is alſo that which followeth: Let there be two ſimilar Candles A and B, (ſee PLATE I. *Fig.* 5.) which are about three Feet diſtant from the Board CD, in which is a large Hole at G; and let them be ſo diſpoſed, that the Eye E cannot ſee the Candle A, nor the Eye F the Candle B; if both Eyes are directed to the Hole G, both the Candles ſhall appears as one in that Hole; for tho' the Candle A is ſeen by the Eye F in the viſual Line FA, and the Candle B by the Eye E in the viſual Line EB; yet, as we always refer the Place of Objects to the *Choropter* or the Plan on which our Eyes are fixed, both Candles muſt be ſeen in the ſame Place G where the optic *Axes* FA and EB meet; and being ſeen in the ſame Place, they muſt appear as one; as is agreeable to Experience.

And as different Objects, when ſeen in the ſame Place, appear ſingle; ſo, on the contrary, the ſame Object, when ſeen in different Places, always appears multiplied, according to the Number of Places in which it is ſeen. Thus, in the former Experiment, if the Hole is ſmall, and if the Eyes are directed to the middle Point H betwixt the Candles, the Hole ſhall appear double. Thus alſo, when one of the Eyes is diſtorted by a Spaſm in any of its Muſcles, or by the Preſſure of the Finger, all Objects will appear double; the Reaſon is, becauſe in both theſe Caſes the Object is ſeen in two different Places; as ſhall be explained afterwards, when we come to treat of the *Phænomena* of Viſion. Thus alſo, when we look at an Object thro' a *Polyedron* or Multiplying-glaſs, the Object appears multiplied according to the Number of plain Surfaces, thro' which it is ſeen; becauſe each of theſe Surfaces, by Reaſon of the different Refraction that is made by them, makes the Object to be ſeen in a different Place; as thoſe who have any Knowledge in Optics will eaſily underſtand. But to return;

§ 7. GALEN's other Reaſon for this Conjunction of the optic Nerves, is, that the viſive Rays or Spirits, which, according to him, conſtantly ſtream forth from the Nerves thro' both Eyes, for cauſing Viſion, may, when one of the Eyes is ſhut or loſt, be all determined into the ſeeing Eye, for ſtrengthening its Sight, and ſupplying the Want of the other: It is from this greater Flow of Spirits, he accounts for that Enlargement of the Pupil that is always to be obſerved when the other Eye is ſhut or loſt; and as he imagined that the Pupil had no Motion, but that of dilating itſelf when one of the Eyes was ſhut or loſt, and again contracting itſelf when the Eye was opened or recovered, he eſteemed this a convincing Proof of his Doctrine.

But that what GALEN ſays on this Head may be the better underſtood, it muſt be remembered, that tho' he was a great Diſciple, and in many Things a ſlaviſh Follower of ARISTOTLE, from whom he borrowed moſt of that Philoſophy with which his Writings abound; yet with regard to the Manner in which Viſion is produced, he rejects the Opinion of ARISTOTLE, and rather embraces that of PLATO, who ſuppoſed, that both from the Eye and the Object there came ſubſtantial *Effluvia*, which meeting Half-way and encountering the ocular *Effluvia*, the latter were beat back again to the Eye, and there communicated the Impreſſion they had received from thoſe *Effluvia* which came from the Object, and ſo produced the Senſe of Seeing. This being GALEN's Opinion with regard to Viſion, he might, from ſuch Principles, well ſuppoſe, that the Sight behoved to be ſtrengthened in Proportion to the Flow of viſual Rays or Spirits, which, ſtreaming forth thro' the optic Nerve and Eye, enlarged the Pupil; and that the Conjunction and Communication of thoſe Nerves enabled us to determine the whole of theſe Spirits to the ſeeing Eye, for ſtrengthening its Sight, when the other was ſhut or loſt.

§ 8. But as GALEN is greatly miſtaken, both in his Theory of Viſion, and in his Theory of the Pupil's Motion, as will appear from what is to follow, we need not now waſte much Time in confuting him; and therefore ſhall only obſerve,

Firſt, That this Doctrine can receive no Confirmation from the above mentioned Dilatation of the Pupil; and that becauſe that Dilatation never proceeds from any Efflux of viſual Rays or Spirits preſſing open the Pupil, as GALEN imagined, but from other Cauſes, to be explained afterwards in their proper Place.

Secondly, This Doctrine is repugnant to what has been before noticed with regard to the Conjunction of the optic Nerves, which are only united by a cloſs Coheſion, without any Confuſion of Subſtance, or Communication of Pores, thro' which the Spirits of both

Nerves can paſs to either of the Eyes, as need requires.

Thirdly, I deny, that, when one of the Eyes is ſhut or loſt, the Sight of the other is ſtrengthened: It is indeed true, that, when one of the Eyes is ſhut or loſt, its Pupil will be enlarged; becauſe it always proportions itſelf to the Senſation of Light; whence the Pupil of the ſeeing Eye, which, for Reaſons that will be explained afterwards, always ſympathizes with and follows the Motions of the other, will alſo be enlarged; and being thus enlarged, Objects muſt appear ſomewhat more bright and luminous, becauſe then more Light goes to the Formation of their Pictures on the *Retina*. But this does not make the Sight of that Eye ſtronger, it being only in proportion to the Light that enters the Eye: Whence we conclude, that the Sight is not ſtrengthened by any greater Flow of Spirits, as GALEN imagined.

§ 9. What poſſibly might have contributed to have led GALEN into this Miſtake, is a Suppoſition, which I find many ſtill entertain concerning the Degree of Brightneſs of an Object when ſeen with one Eye, and with both; at firſt View, one is apt to imagine, that an Object ſeen with both Eyes ſhould appear twice as bright and luminous as when ſeen only by one; and that becauſe each Eye gives us an equal Idea of the Object; which Idea, it may therefore be thought, ſhould be twice as ſtrong and lively, when both Eyes concur, as when only one. From this Suppoſition, it is probable, that GALEN might have been brought to conclude, that, as the Appearance of Objects is much the ſame when ſeen either with one or with both Eyes, the Sight of the open Eye behoved to be greatly ſtrengthened, while the other Eye remained ſhut; and for ſtrengthening it, he might be led to frame this Hypotheſis, of a greater Flow of Spirits to the open Eye.

But it has been before demonſtrated, from Dr. JURIN's accurate Experiments, that Objects ſeen with both Eyes are ſo far from being twice as bright and luminous as when ſeen with one only, that they are only about a thirteenth Part brighter; which is ſo trifling a Difference, that no body can be ſenſible of it, in looking at an Object alternately with one Eye and with both; and therefore there was no need of framing any Hypotheſis to account for it. Beſides, as the Pupil always dilates when the other Eye is ſhut, if this Dilatation lets into the Eye but a thirteenth Part more of the viſual Rays, this will be ſufficient to make the Object truly, as well as to Senſe, as bright and luminous as when it was ſeen with both Eyes.

§ 10.

§ 10. Having thus rejected GALEN's Opinion with regard to the Cauſe of this Conjunction of our optic Nerves, it may be expected I ſhould now fix on ſome thing elſe.

What to me appears moſt probable, is, that Nature hath conjoined theſe Nerves to ſtrengthen and fix them in their Courſe; which being long, might have expoſed them to the Danger of being ſhaked, hurt, or turned out of their Place, on any quick or violent Motion, had they not been fixed and ſtrengthened by this Junction. Nor is it any ſolid Objection to this, that in ſome Creatures, ſuch as the Chamelion, Birds and Fiſhes, they are always disjoined; ſince Nature in ſuch Caſes may have made uſe of other Means for fixing them, which ſhe was not obliged to follow in Man and other Animals: And the like Anſwer may be made to the few Inſtances that may be given of their having been found disjoined in Man.

A ſecond Reaſon for this Conjunction of theſe Nerves, is, that they might be perpendicular to the Eyes, at the Place of their Inſertion: But, for underſtanding what Benefit we receive from this, it muſt be remembered, that Monſ. MARIOTTE has demonſtrated, that our Eyes are inſenſible at that Place where the optic Nerves enter them: Whence it became neceſſary that theſe Nerves ſhould pierce the Globe on the Inſide of the optic *Axis*; for, had they pierced the Globe in the optic *Axis* itſelf, then the middle Part of every Object had been inviſible; and where all things contribute to make us ſee beſt, there we had not ſeen at all. We muſt likewiſe have loſt ſome Part of an Object, if the optic Nerves had been placed either above or below, or on the Outſide of the optic *Axis*; becauſe an Object may be ſo placed, as that all the Rays which come from one certain Part of the Object, may fall upon the upper, under, or Outſide of both Eyes: But it is impoſſible that they ſhould ever fall upon the Inſide of both Eyes; and therefore, by this Inſertion of the Nerves on the Inſide of the optic *Axis*, that Part of the Object which is loſt to one Eye, is always viſible by the other.

Now, ſince it was neceſſary that the optic Nerves ſhould have been inſerted on the Inſide of the optic *Axis*, it was alſo neceſſary that they ſhould have been perpendicular to the Eye, at the Place of their Inſertion; for, by that means, this Place, which is always inſenſible, is made the leaſt that is poſſible; and therefore Nature has wiſely brought our optic Nerves together at the *Cella Turcica*, that from thence they might proceed perpendicularly to the Place of their Inſertion on the Inſide of the optic *Axis*; whereas, had they proceeded in a ſtreight Courſe from their Origin in the Brain to the Place of their Inſertion, they behoved to have fallen on the Eye obliquely; which would have enlarged the Place of their Inſertion, and conſequently would have enlarged that inſenſible Part in the Bottom of the Eye.

CHAP. X.

Of the Aqueous Humour.

SECT. I. WE have before obſerved, that the aqueous Humour lies partly before and partly behind the *Uvea*, and fills all that Space which is betwixt the *Cornea* and the *Cryſtalline*. The Space betwixt the *Uvea* and *Cornea* is called the *Anterior Chamber of the aqueous Humour*, and the Space betwixt the *Uvea* and *Cryſtalline* is called its *Poſterior Chamber*: So that the *Uvea* divides this Humour into two Parts, excepting in its Middle, where this Coat is perforated with the Pupil; by which means the aqueous Humour lying before the *Uvea* communicates with that lying behind it.

The famous Monſ. BRISSEAU, Phyſician to the King of *France*'s Hoſpitals, and Profeſſor of Medecine in the Univerſity of *Doway*, was the firſt I find who gave the Name of *Chambers* to theſe two Spaces. In this he was ſoon followed by the learned HEISTER, and now the Term is univerſally received, on account of its Propriety and Significancy.

I have already noticed, from Dr. PETIT, that the whole of the aqueous Humour weighs only four Grains; of this, according to the ſame Author, only about a third Part is lodged in the poſterior Chamber; and therefore the Quantity contained iu this Chamber muſt only be one Grain and one third; and the Quantity in the anterior Chamber two Grains and two thirds.

This Humour, like the *Cornea* and the other Humours of the Eye, is very clear and tranſparent. They are tranſparent, that none of the Light may be intercepted; and they are clear, that Objects may be ſeen in their own proper Colours; for, were they tinged with any Colour, all Objects would alſo appear tinged with that Colour.

§ 2. The Mechaniſm by which this tranſparent Purity is preſerved, is the ſecretory Power of the *Uvea* and *Choroides*, by which the

Blood, which goes to ſupply Nouriſhment to the *Cornea* and *Humours* of the Eye, is freed of all thoſe opaque black Particles, which could in the leaſt tarniſh them, or diminiſh their pure Tranſparency. Theſe black Particles, which may be called the *Lees* of the Blood, are therefore retained in the *Choroides* and *Uvea*, which are ſullied and blackned therewith. And this may poſſibly be one Reaſon why thoſe Creatures that ſee beſt, ſuch as Eagles, and other Birds of Prey, have the Pupil very black; and, on the contrary, the Owl, Lion, and other Animals whoſe Sight is not ſo good, have this Hole leſs black; becauſe the Bottom of their Eyes is not covered with this black Pigment.

I know, that moſt Authors ſuppoſe, that the Blackneſs of the *Uvea* ſerves only for rendering this Membrane more opaque, that no Light may enter the Eye but what paſſes the Pupil; and that the Blackneſs of the *Choroides* has no other Uſe, but to ſtifle the Rays of Light that fall on it, that they may not be reflected back upon the *Retina*, which might efface the Images of Objects, or at leaſt render them more confuſed and imperfect.

But, if we conſider, that the convex Back-part of the *Choroides*, next the *Sclerotica*, is likewiſe covered with this black Pigment, and that in all Animals, even thoſe which have its concave Side next the *Retina* of another Colour, as AQUAPENDENS, in his Treatiſe *de Oculo* (*Sect.* 1. *cap.* 4.) obſerves, we cannot but think, that it likewiſe contributes to the Preſervation of that pure Tranſparency in the *Cornea* and Humours of the Eye, which is ſo neceſſary for the Tranſmiſſion of Light; and that becauſe there appears no other Reaſon for the black Colour upon the Back-part of the *Choroides.* Thus, as I have before obſerved, the Lion, Camel, Bear, Ox, Dear, Sheep, Dog, Cat, and many other Quadrupeds, and even ſome of the Bird-kind, that are not endowed with a good Sight, ſuch as the Owl, and other nocturnal Birds, which have the Inſide of the *Choroides* of a ſplendid blue, green, yellow, pearl, or other bright Colour, are never found to want a conſiderable Quantity of this black mucuous Pigment upon the convex or Back-ſide of this Membrane; which can ſerve for nothing elſe, but for rendering the Aliment, which goes to the *Cornea* and Humours of the Eye, more pure and free from thoſe groſs black Parts which might tarniſh them, and render them unfit for tranſmitting the Light.

§ 3. This may be illuſtrated from what happens in Jaundices; for, as in this Diſeaſe the whole Body becomes yellow from the

Bile which is not duly ſecerned in the Liver, which yellow Colour again diſappears ſo ſoon as the Obſtruction is removed; ſo, from a manifeſt Analogy, there ſeems Reaſon to think, that the Eye would ſoon loſe its Tranſparency, were it not for the ſecretory Power of the *Uvea*, and *Choroides* by which the Blood is purified and freed of its moſt opaque black Parts. Whence it is to be obſerved, that Animals, whoſe Blood abounds moſt with blackiſh Particles, have always thoſe Membranes proportionally of a more intenſe black Colour: For it is remarkable, that thoſe who have moſt Blackneſs in their Hair or Feathers, have thoſe Membranes alſo moſt black. But I have dwelt too long on this Head, more eſpecially that it will fall to be ſpoke to again in treating of the Uſes of the Parts of the Eye. But as it naturally fell to be noticed here, I could not altogether omit it.

§ 4. The aqueous Humour is not only clear and tranſparent like Water, but is alſo nearly of the ſame Conſiſtence; for, as NUCK has obſerved, in many different Animals, its Conſiſtence very much approaches that of the White of an Egg, well agitated into a thin Liquor: But, at different Ages, both its Colour and Conſiſtence is altered. In youth, it is very thin, clear and tranſparent;

rent; but it becomes thicker, more muddy, and leſs tranſparent, as we advance in Years: And in old Age it is frequently whitiſh; which very much darkens the Sight, by obſtructing the Rays of Light in their Paſſage to the *Retina*. And this is one Reaſon why many elderly Perſons do not reap all that Benefit from Spectacles which they are intitled to expect, when by them the Pictures on the *Retina* are made diſtinct.

The Reaſon why this Humour is made ſo thin and fluid, is, that the Pupil might be the more eaſily enlarged and leſſened, according as its longitudinal or circular Fibres contract; for, had it been of a Conſiſtence like that of the Cryſtalline, or even that of the vitreous Humour, it behoved to have reſiſted the Motion of the *Uvea*, by which this Aperture is dilated and contracted.

§ 5. This Humour is altogether void of Smell, unleſs it be kept for ſome Time, and then it ſtinks like the White of an Egg that has become putrid. As for Taſte, it is almoſt inſipid, having only ſome very ſlight Saltiſhneſs, which is ſcarce perceptible but in old Animals. It appears to be of a very Spirituous Nature, inſomuch that a great many Authors, of whom Dr. KEILL is one, thought that it could not be made to freeze in the greateſt Froſt. This I find was the general Opinion of Phyſicians and Anatomiſts, till towards the Beginning of this Century. But in this they were much miſtaken; as appears from the Experiments and Obſervations made on frozen Eyes, by HEISTER, MORGAGNI, PETIT, and others. And the famous BOYLE has alſo given us ſome Obſervations on frozen Eyes, long before any of theſe Gentlemen wrote any thing on the Subject.

§ 6. But tho' this Humour can be made to freeze, it is nevertheleſs very ſpirituous and volatile, and, by exhaling thro' the Pores of of the *Cornea*, it diminiſhes conſiderably in a very little time; as all may have obſerved in the Eye of an Ox, or other Animal, whoſe *Cornea* after Death ſoon ſhrivels and becomes flaccid, from the Exhalation of this Humour. The other Humours do alſo diminiſh by Evaporation, when the Eye is taken out of the Head, and, being freed from its Fat and Muſcles, is ſuſpended in the Air. But this Evaporation is very inconſiderable, when compared to that of the aqueous Humour, which ſometimes is altogether evaporated, when the other Humours have loſt but a ſmall Proportion of their Weight; as Dr. PETIT has obſerved (*Mem. de l'Acad. ann.* 1728.)

§ 7. This Evaporation of the aqueous Humour, I apprehend, is the chief Cauſe why the Pupil is ſometimes found contracted after Death.

But, that this may be the better underſtood, it muſt be obſerved, that the natural State of the Pupil is a State of Dilatation, and its Contraction a State of Violence, occaſioned by the Contraction of the circular Fibres of the *Uvea.* This is manifeſt from its being ſo very large in a *Syncope, Apoplexy, Gutta Serena, &c.* for in theſe, and ſuch like Caſes, as the Eye is altogether inſenſible of the Light, ſo all the Muſcles and muſcular Fibres have loſt their Tone and their Power of Contraction; and therefore the Pupil muſt of itſelf fall into that State which is moſt natural to it. But, ſeeing in thoſe Caſes it is always much dilated, it follows, that this is its natural State, and that its Contraction is a State of Violence, cauſed by the Contraction of its circular Fibres. And this is ſtill further confirmed by that dazzling Uneaſineſs which we all feel from ſtrong Light, immediately after waking, when the Pupil may alſo be ſeen greatly enlarged.

This being premiſed, it may be aſked, whence it comes to paſs that the Pupil, after Death, in place of being enlarged, is ſometimes found greatly contracted. That this is true, has been obſerved by the accurate Mr. WINSLOW (*Mem. de l' Acad. ann.* 1721.) He there tells us, " that in the greateſt Part of " the human Subjects he had examined, he " found the Pupil of a moderate Size, and ſome-

"times greatly contracted, but never much "dilated."

There is alſo a memorable Paſſage in GALEN, to the ſame purpoſe, which ſerves to ſhew that WINSLOW was not the firſt who obſerved this Contraction, as ſome have imagined. His Words, as they ſtand in LACUNE's *Epitome*, are: *Porro, ſi alterum oculum clauſerimus, alterum aperientes, amplificatam et dilatatam, ac veluti inflatam pupillam cernimus, quod illuc major copia ſpiritus confluat. At in mortuo animali, vel ſi humor tenuis evacuatus non ſit, laxa tamen pupilla videtur; quod nimirum ſpiritus quidem ipſe levior et tenuior exiſtens, facile ante anatomen evacuatur; humor autem adhuc remaneat ſenſibilem evacuationem poſtulans.* (*De Uſu Partium, lib.* x.)

§ 8. Now, this Contraction of the Pupil, after Death, at firſt View, ſeems to be impoſſible, on the Suppoſition that its natural State is a State of Dilatation; and from thence alſo it may be alledged, that its natural State is rather a State of Contraction: But, if the Matter ſhall be duly conſidered, ſuch Difficulties will ſoon be removed. For,

Firſt, WINSLOW does not ſay, that the Pupil is never dilated after Death, but only, "that he never found it much dilated;" which implies, that he ſometimes found it ſomewhat dilated, tho' not to an extraordinary

Size; and that it may be found conſiderably dilated, if examined immediately after Death, and before the aqueous Humour has been diminiſhed by Evaporation, may reaſonably be preſumed, from what has been obſerved of its State in Faintings, the *Apoplexy*, *Amauroſis*, and immediately after waking. I had occaſion lately to look at the Eye of a dead Cat, and found the whole Eye laid open, inſomuch that no Veſtige of the *Iris* was to be ſeen; which is a further Confirmation of this Doctrine. Add to this, that Mr. MERY, who it ſeems always happened to examine the Eyes ſoon after Death, poſitively affirms, that after Death, the Pupil is always dilated, (*Hiſt. de l'Acad. ann.* 1710.) The Paſſage is as follows: *L'état où ſeront les fibres de l'iris, après la mort, ſera donc celui où leur reſſort les tient naturellement*; *or après la mort la prunelle eſt toujours dilatée*; *c'eſt-à-dire, que les fibres droits de l'iris ſont raccourcies*; *elles le ſont pareillement et dans le goute ſereine, et dans la ſyncope, dont l'une eſt une mort de l'oeil par rapport à la viſion, et l'autre une petite mort de tout l'homme, et toutes deux une privation d'eſprits. C'eſt dont l'état naturel des fibres de l'iris que d'eſtre raccourcies, et de tenir la prunelle ouverte.* But,

§ 9. *Secondly*, Tho' WINSLOW ſometimes found the Pupil greatly contracted, yet this does not prove that to be its natural State, or weaken the Arguments from which we conclude that its natural State is a State of Dilatation; and that becauſe this Contraction, after Death, may ariſe from other Cauſes, and particularly from the Cauſe already mentioned, the Evaporation of the aqueous Humour: For WINSLOW does not tell us how long his Subjects had been dead; but, as from the Paſſage ſo lately quoted from him, it appears, that he ſometimes found this Aperture a little dilated, ſometimes (and indeed for the moſt Part) moderately contracted, and ſometimes greatly contracted; it ſeems reaſonable to ſuppoſe, that theſe different States of the Pupil proceeded from its being examined ſooner or later after Death; and that immediately after Death, it was dilated, but afterwards contracted itſelf more and more, in proportion to the Evaporation of the aqueous Humour, that is, in proportion to the Time the Perſon had been dead, when his Eyes were examined: For, as in the *Exophthalmia*, or immoderate Fullneſs and Diſtenſion of the Globe, the Pupil is always much dilated, of which NUCK gives an Inſtance, where ſcarce a Veſtige of the *Iris* was to be ſeen, (*de Duct. Ocul. Aquoſ.*) ſo, on the contrary, when this Humour becomes leſs in Quantity, the Pupil always contracts. This is no new Diſcovery: It was obſerved by GALEN, as appears from the following Paſſage, which I ſhall ſet down at large, as it ſtands in the Tranſlation: *Cæterum* (ſays he *de Symptom. Cauſ. lib.* 1.) *incredibile quidam, nec fieri vulgo ſolitum, in puero vidimus, qui Stylo in pupillæ loco fuerat compunctus; nam quum ſtatim effluxiſſet aquoſus humor, tum pupilla ipſa minor eſt reddita, tum tota cornea apparuit rugoſior. Cæterum ſanatus poſtea recte vidit, collecto, ſcilicet, paulatim in eo qui effluxerat humor.*

That this Contraction of the Pupil, after Death, proceeds from a Diminution of the aqueous Humour, and not from that's being its natural State, is ſtill further confirmed, from what may be obſerved in the *Microphthalmia* or Atrophy of the Eye; for, in that Diſeaſe, from whatever Cauſe it may have proceeded, the Pupil is always contracted, which can proceed from nothing but a Penury of the Humours, and eſpecially of the Aqueous. Nor is it to be doubted, but the Smallneſs of the Pupil, which always takes place in old Men, is likewiſe in a great Meaſure owing to the ſame Cauſe; for in them the Eyes are ſmall, ſunk, flatt, and ſhriveled, from a Scarcity of the Humours which uſed to diſtend and plump the Eye; whence the Pupil becomes ſmall, as was alſo obſerved by GALEN; *Solius etiam Corneæ ipſius corrugatio* (ſays he, *de Symptom. Cauſ. lib.* 1.) *qualis ſenectuti confectis ſolet ſemper accidere, ſimiliter viſum offendit; cæterum, ſi pupilla ſimul ſit imminuta, ſcire licet* *aquoſum quoque humorem imminutum exiſtere; ſin vero æqualis permanſerit, ad ſolam ceratoidem affectus pertinet.*

§ 10. For underſtanding how a Diminution of the Humours of the Eye may occaſion a Contraction of the Pupil, ſee *Fig.* 6. PLAT. I. where AVDVA is a Section of the Eye of an adult Perſon in its natural turgid State, C the Centre of the Eye, CV, CA, CV, *Radii*, which, according to PETIT's Obſervations, are each five Lines and one third part; AD its *Axis*, which, according to the ſame Author, is eleven Lines and one third part, *viz.* twice the *Radius* (or ten Lines and two thirds), and two thirds of a Line more, occaſioned by the Prominency of the *Cornea*; VV, the Diameter of the *Uvea*, which is five Lines; P the Pupil in its dilated State, which, from what I have ſaid before, is in grown Perſons about one third of the *Uvea*, or one Line and two third parts.

Now, let it be ſuppoſed, that the Humours of the Eye are diminiſhed, ſo as to reduce its *Radii* to two third parts of a Line leſs than they were before; and let *uauu* be the Section of the Eye thus reduced, of which C*u* and C*u* are *Radii*, whoſe Length will be four Lines and two third parts: It is plain, that, by the ſhrinking of the Eye from VAV to *uau*, the extreme Points of the *Uvea* V and V will be made to move along the *Radii* VC, VC, to the Points *u* and *u*, and that the *Uvea* of this ſhrunk Eye will be *u u*.

Now, ſince in the Triangle VCV, the Line, *u u* is parallel to VV, it follows, that CV : VV :: C*u* : *uu*. Hence $uu = \frac{VV \times Cu}{CV} = \frac{5 \times 4\frac{2}{3}}{5\frac{1}{2}}$ $= 4\frac{3}{8}$; that is, the *Uvea* in this ſhrunk Eye will be reduced to four Lines and three eight Parts, which being five eight Parts of a Line leſs than before, the Pupil alſo muſt now be $\frac{5}{8}$ of a Line narrower than in its moſt dilated State. But the Pupil, in its moſt dilated State, is, as has been ſaid, one Line and $\frac{2}{3}$, from which if $\frac{5}{9}$ are deduced, there will remain $1\frac{1}{24}$ for the Wideneſs of the contracted Pupil *p*; but this Pupil, which, in its moſt dilated State, is one Line and $\frac{2}{3}$ in Diameter, cannot, by the ſtrongeſt Light, be made to contract to a leſs Size than one Line and $\frac{1}{9}$ Part, which is $\frac{2}{3}$ Parts of its former Diameter; and therefore it is more contracted by this Diminution of the Humours, than it can be by the ſtrongeſt Light, and conſequently muſt appear greatly contracted; as WINLSOW obſerved.

If it ſhould be alledged, that I have ſuppoſed a greater Diminution of the Humours, and, in conſequence of that, a greater Shrinking of the Eye than what can readily happen for a conſiderable Time after Death; to this it might be anſwered, that the Diminution of the Humours here ſuppoſed, is not ſo great as what happens in the Space of twenty four Hours after the Eye is taken out of the Head and ſuſpended in the Air; as is evident from PETIT's Experiments, *Mem. de l'Acad. ann.* 1728.

But, as it muſt be acknowledged, that this Evaporation muſt be a great deal leſs while the Eye remains in the Head, I ſhall here ſhew how this Contraction of the Pupil may happen to as great a Degree, tho' there be not ſo great a Decay in the Humours as is here ſuppoſed; for, as in an Eye that hath been taken out of the Head, and ſuſpended in the Air, the aqueous Humour always loſes moſt by Evaporation, in ſo much that in twenty-four Hours it is ſometimes quite diſſipated, while the other Humours have loſt but a ſmall Proportion of their Weight; ſo when the Eye remains in the Head, which may indeed retard the Evaporation of theſe other Humours, this Evaporation of the aqueous Humour will continue much the ſame; and therefore the Tunicles of the Eye, at the Edge of the *Choroides*, where it joins the *Uvea*, for want of a Preſſure from within at that Place from the aqueous Humour, will be made to fall inwards towards the *Axis* of the Eye, by which the *Uvea* muſt become narrower, and conſequently the Pupil muſt be more contracted than what would happen, did the whole Eye contract uniformly over all.

Whence we may ſee, how the Pupil may be greatly contracted from a Diminution of the aqueous Humour alone, tho' the other Humours ſhould continue in their natural Quantity; as was obſerved by GALEN, when the aqueous Humour was voided by a Wound in the *Cornea*. And, I am perſuaded, from the Smallneſs and Sunkneſs of the Eyes of elderly Perſons, and from the Need they have of Spectacles, that there is a great Decay and Scarſity of the Humours of the Eye, eſpecially of the Aqueous, from which Decay that Contraction, which is to be ſeen in their Pupils, is chiefly to be accounted for; as has been before noticed.

§ 11. I have ſaid, that the aqueous Humour ſoon Putrefies, and acquires a Smell like that of a rotten White of an Egg. Now, from this it follows, that, if this Humour continued in the Eye without Circulation, it would ſoon, by the Heat of the Body, be made to degenerate into an acrid Corroſive *Ichor*, which, by fretting and corroding the Parts, would ſoon ſpoil the Eye, and render it for ever uſeleſs.

§ 12. and this Circulation is yet further confirmed by what happens in Wounds of the

Eye; for, after that the aqueous Humour has run out by the Wound, and the *Cornea* thereby become flaccid; in a few Days it again becomes plump, from a freſh Supply of this Humour.

This likewiſe was known to GALEN, as appears from the Paſſage ſo lately quoted from him. But, for a long Time, it ſeems, the generality of Phyſicians either over-looked this Paſſage, or did not believe it; for HEND. *ab* HEERS was greately ſurpriſed to find, that the Eye of a Gentleman's Daughter, and thoſe of a Cock, when wounded ſo that the *Cornea* ſunk, were again reſtored by a *Lithuanian* Chymiſt, who paſſed for a Conjurer, by the Uſe of a Liquor found in *May* in the *Veſiculæ* of Elm: (*Obſ. Med. Obſ.* 4.) And thoſe that are knowing in the Hiſtory of Medicine, will remember what Noiſe the famous BURRHY made about the Year 1662 with his Eye-water, which being injected into the Eye of a Dog, Gooſe, *&c.* after that all the Humours, the Cryſtalline and Vitreous, as well as the Aqueous, had been expreſſed by a Wound made in the *Cornea*, the Animal, to every body's Surpriſe, in a few Days recovered its Sight again, and no Defect was to be ſeen in the Eye, excepting a very ſlight Scar on the *Cornea*. (*Vid.* BARTHOLIN. *Epiſt. Cent.* 3. *Epiſt.* 99.

and 100. *item Act. Med. Hafn. ann.* 1671. and 1672. *Obſ.* 132. and 133.)

When Phyſicians came at laſt to believe that the Sight could be reſtored after the Eye had loſt the aqueous Humour by a Wound, they generally attributed the Cure to certain ſpecific Applications, which they extolled as valuable Secrets, ſuch as the above Water found in the *Veſiculæ* of the Elm, Waters drawn from *Celendine* and other choiſe Ingredients, Waters made of Vitriol of *Mars*, myſteriouſly prepared, Powders and Waters made of *Catechu*, and other valuable Ingredients, the *Noſtrum* of BURRHY communicated to the famous BARTHOLINE, *&c.* But ſuch Wounds need no ſuch celebrated *Arcana*. Nature herſelf eaſily cures them, without any Aſſiſtance, provided only ſuch Applications are made as may prevent Inflammation and a Flux of Humours on the Eye. Of this Multitudes of Obſervations are every where to be met with in our more modern Authors.

In the Year 1670, this was experimented upon a Gooſe by Dr. DANIEL MAJOR: The aqueous Humour of both Eyes they let out ſo that the Eye fell, and the Gooſe became quite blind: But, without the Uſe of any Medicine, in about two Days time, Nature repaired the watry Humour again, the Eyes returned to their former Turgency, and, which ſhows how little ſuch Stories were at that Time credited, the Gooſe was in a Week after produced ſeeing, before no leſs than 28 or 30 Spectators: (*Ephem, Germ, Tom.* 1. *Add. ad Obſ.* 117

The like Experiment was made by SCRIVERIUS upon a Gooſe, a Cock, and a Hen; all of whom, after having the whole of the Humours ſqueezed out of the Eyes, again recovered their Sight, without the Aſſiſtance of any Medicine. (Act *Hafn*: *ann.* 1671, and 1672, *Obſ.* 133.) And we ourſelves may have frequent occaſion to ſee this verified with regard to the aqueous Humour, in the Operation of the Cataract; for the aqueous Humour that always runs out, when, from the Difficulty of the Operation, the Operator is obliged to keep the Needle long in the Eye, is again ſoon ſupplied; as every body muſt have obſerved who have been verſant in that Operation. And in the new Way of this Operation, in which the Cryſtalline is extracted, it is always attended with a total Diſcharge of this Humour, which nevertheleſs is ſoon reſtored, without the Aſſiſtance of Medicine, and even is increaſed to a greater Quantity than what is natural, to fill the Place of the Cryſtalline.

§ 13. This gives occaſion to a Queſtion, How this Humour is ſupplied, and by what means it circulates? The learned NUCK, who has acquired no ſmall Reputation by his Anatomical Works, pretends to have diſcovered a Veſſel which brings this Humour into the Eye, and after him HOVIUS publiſhed a Treatiſe concerning the Circulation of thoſe Humours, wherein he pretends to have clearly demonſtrated the abducent as well as adducent Veſſels.

But to me it appears, that thoſe Veſſels muſt be much ſmaller than what can be obſerved by the Eye, otherwiſe the Humours they carry would be compoſed of groſs opaque Parts, altogether unfit for tranſmitting the Rays of Light; and therefore it ſeems more than probable, that HOVIUS has impoſed on himſelf and others, in the Account he has given of thoſe Veſſels, as well as NUCK.

What I eſteem moſt probable in this Matter is, that the Blood brought to the *Choroides* by the Arteries already deſcribed, is freed from its moſt opaque groſs Parts by the Secretion of that black *Mucus*, upon both Sides of the *Choroides* and *Uvea*; and that it is further attenuated and ſubtilized by the many Turnings and Windings thoſe Arteries make in forming *Plexuſes* and Net-works upon theſe Tunicles; after which, its moſt fluid and tranſparent Part is received into ſmall lateral Branches, from which again others yet ſmaller ariſe, and perhaps again from theſe yet many Serieſes of other Veſſels ſtill ſmaller and ſmaller; which laſt being extremely ſmall, muſt exclude all the groſs opaque Particles, and admit only the moſt ſubtile and tranſparent ones. And we are of opinion, that theſe laſt Veſſels, which, by Reaſon of their Smallneſs, are quite inviſible, by opening every where on the Inſide of the *Cornea*, both Sides of the *Uvea* and Fore-part of the Capſul of the cryſtalline Humour, *&c.* do conſtantly diſcharge this tranſparent Liquor into its proper Cavity; which, that it may not ſtagnate, is again abſorbed by ſmall Pores, which are the Mouths of lymphatic Veins correſponding to theſe Arteries. And this ſeems to be the true natural way of Circulation of this Humour, and does excellently well account for its Regeneration, after it has been evacuated by a Wound in the *Cornea*.

§ 14. We are the more confirmed in this way of Circulation of the aqueous Humour, from what happens in other Parts of the Body. In the Cavity of the *Pericardium*, Ventricles of the Brain, the Cavity of the *Thorax* and *Abdomen*, and, in general, in all the Cavities of our Body, there is always found more or leſs of a ſerous Liquor, which can only come from the Arteries, which, by ſmall lateral Branches, muſt convey this Liquor into theſe Cavities:

vities: But, were it not again abſorbed, it would ſoon be accumulated in too great Plenty, and in the Head form a *Hydrocephalus*, in the *Thorax*, a *Hydrops Pectoris*, and in the *Abdomen*, a *Hydrops Aſcites*, and ſo forth; and therefore provident Nature has in all theſe Cavities wiſely placed Pores by which this Liquor is again returned into the Veins; it being a general Rule, That wherever there are exhaling Veſſels, there are likewiſe inhaling or abſorbent ones. Thus in the Skin, as the *Perſpiratio Sanctoriana* is conſtantly exhaled, ſo by abſorbing Pores, Humidities are conſtantly inhaled, as evidently appears from what happens from the Application of Fomentations, Catapláſms and Bliſters, and eſpecially from the Application of Mercureal Unctions.

§ 15. When theſe exhaling arterial Veſſels of the Eye are any way enlarged, or when their correſponding abſorbent ones are obſtructed, then the aqueous Humour will be accumulated in too great a Quantity, and, by diſtending the *Cornea*, will form that painful and obſtinate Diſeaſe called *Exophthalmia* and *Hydrophthalmia*, in which the Pupil is always enlarged; as has been before noticed.

CHAP. XI.

Of the Cryſtalline Humour.

SECT. 1. WE have before obſerved, that the Cryſtalline is the moſt ſolid of all the Humours of the Eye. From its Solidity and Tranſparency the Antients concluded, that it was nothing but a thick congealed Humour. But, tho' it be commonly called a Humour, yet it is really made up of ſolid Parts; for, in a Cryſtalline that has been dried, or that has been hardened, either by boiling in Water, or by being ſteeped in one Part of *Aqua Fortis* and three Parts of common Water, it is eaſy to obſerve, that it is made up of many thin ſpherical *Laminæ* or Plates lying within each other, like ſo many Boxes of equal Figures, but different Magnitudes, or rather like the different Pellicles or Plates which compoſe an Union. Mr. LEEUWENHOEK reckons there may be two thouſand of them in one Cryſtalline, from the uttermoſt to the Centre. Every one of thoſe *Laminæ* or Scales, he ſaith, he hath diſcovered to be made up of one ſingle Fibre or fineſt

Thread, wound in a moſt ſtupenduous Manner, this way and that way, ſo as to run ſeveral Courſes, and meet in as many Centres, and yet not to interfere or croſs one another in any one Place. In Oxen, Sheep, Hogs, Dogs and Cats, the Thread ſpreads into three ſeveral Courſes, and makes as many Centres; in Whales five; but in Hares and Rabbets only two. In the whole Surface of an Oxe's Cryſtalline, he reckons there are more than 12,000 Fibres juxta-poſited. But, for the right and clear underſtanding of the Manner of this admirable Piece of Mechaniſm, I ſhall refer to his Cutts and Deſcriptions in *Philoſ. Tranſ.* N° 165. and 293.

I know the Truth of this ſurpriſing Mechaniſm has been queſtioned by ſome ingenious Men. But it has ſince been confirmed by the Obſervations of others, and particularly of the learned Mr. DERHAM, who, in his *Phyſico-theology*, undertakes to ſhew it to any body with the Help of a good Microſcope.

§ 2. Now, the Cryſtalline, tho' it be all very firm and ſolid in reſpect of the other Humours, yet it is not all throughout of the ſame Conſiſtence being outwardly like a thick Gelly, but towards the Centre as conſiſtent as hard Suet. This external ſoft Part ſeems to be about the third of its whole Bulk. Thoſe who maintain that the Cryſtalline

line changes its Figure, and becomes more or leſs convex in proportion to the different Diſtances of Objects, think that its by means of this external ſoft Part that it is diſpoſed to alter its Figure; which could not ſo eaſily happen, were it all of the ſame Conſiſtence with its other Part next the Centre. But as this will fall to be treated of afterwards, in explaining how we come to ſee diſtinctly at different Diſtances, it is unneceſſary to enter upon it here; and therefore I ſhall only remark, in general, that tho' the Cryſtalline does not alter its Figure, yet this Difference betwixt the Conſiſtence of its external and internal Subſtance does not want its Uſe, as will appear from what is to follow.

§ 3. At different Ages this Humour is of different Conſiſtencies. In Children newly born, it is very ſoft, and equally ſo over all. PETIT ſays, that in them, as well as in *Fœtuſes*, it is like cold Broth, (*Boullie refroidie*) *Mem. de l' Acad. ann.* 1730; but it grows firmer gradually as they advance in Years, but moſt ſo in its Middle towards the Centre, where, in time, it becomes firm like Suet; and tho' it continues ſtill to increaſe in Firmneſs, this Inequality in its outward and inward Parts ſtill continues, excepting in old Age, when it has acquired its greateſt Firmneſs, and then this Firmneſs is ſometimes equal over all.

§ 4. The human Cryſtalline is always ſofter than in Birds, Quadrupeds and Fiſhes, all of which have it more and more firm, in the Order they are named. In Fiſh, the central Part is almoſt as hard as Horn; and, on the contrary, its external Part is ſofter than in other Creatures, and is like a Mucilage; ſo that it appears like a double Cryſtalline, the one very ſmall and ſolid in the Centre of the other, which is larger, but of a Subſtance much leſs firm and ſolid.

This little Cryſtalline, which is as it were a *Nucleus* or Kernel to the other, in whoſe Centre it is placed, is never found wanting in the Eyes of Fiſhes; which ſhows that it is not the Effect of blind Fate, but to anſwer ſome wiſe and neceſſary Purpoſe; as ſhall be explained afterwards.

§ 5. I have ſaid, that this Humour has no Colour, being clear and tranſparent like Water: But, about the twenty-fifth or thirtieth Year of our Age, it begins to become a little yellow towards the Centre, which Yellowneſs grows gradually deeper and deeper, and extends more and more towards the Surface, in ſo much that Dr. PETIT found, that the Cryſtallines of a Man of 81 Years old, reſembled two Pieces of beautiful yellow Amber (*Mem. de l' Acad. ann.* 1730.)

This Yellowneſs wherewith the Cryſtalline is more and more tinged as we advance in Years, muſt make all Objects appear more and more tinged with that Colour: Nor does our being inſenſible of any Change in the Colour of Objects, prove to us, that their Colour continues the ſame; for that we may be ſenſible of this Change of Colour, the Tincture muſt not only be conſiderable, but it muſt happen on a ſudden; as has been already ſhewn at ſome Length in the general Idea I have given of the Eye.

§ 6. The Figure of the Cryſtalline is different in different Animals.

In Animals that live conſtantly in Air, as Man, Quadrupeds, and the greateſt Part of the Bird-kind, it is always lenticular; but in Fiſhes, that reſide conſtantly in Water, its Figure is that of a Sphere or Globe; and in thoſe Creatures that are ſometimes in Air, and other times in Water, and who have therefore occaſion to ſee in both, as the Sea-Calf, Cormorant, *&c.* this Humour has a middle Figure, betwixt that of a *Lens* and a Globe.

Theſe different Figures are not the Effect of Chance, but of Skill and Deſign, and are the very beſt that could have been contrived for perfecting the Sight of theſe Animals, being exactly fitted to their ſeveral Circumſtances and Occaſions, as ſhall be ſhewn afterwards.

§ 7. I have obſerved before, that the Cryſtalline *Lens* is more convex behind than before; the Diameter of the Sphere, of which its anterior Segment is a Part, being from 6 to 12 Lines, but moſt commonly about 7¼ or 8 Lines, according to Mr. PETIT's Obſervations; whereas the Diameter of the Sphere, of which its Poſterior Segment is a Part, is commonly only about 5 or 6 Lines. The ſame Author makes the Diameter or Breadth of this *Lens* about 4 Lines, or 4½, and its *Axis* or Thickneſs 2 Lines. But thoſe Meaſures, like the Meaſures of the other Parts of the Eye, differ conſiderably in different Perſons, and even in the ſame Perſon at different Times of Life; and as it is ſcarce poſſible to meaſure the Cryſtalline and the other Parts of the Eye with that Exactneſs that may be depended on, all nice Calculations founded upon ſuch Meaſures, muſt be fallacious and uncertain, and therefore ſhould, for the moſt part, be looked on, rather as Illuſtrations, than ſtrick Demonſtrations of the Points in queſtion.

§ 8. It has been generally thought by Anatomiſts, that all the Humours of the

Eye are of different Denſities, and that the Cryſtalline is much more denſe than either of the other two. Dr. BRIGGS ſays, that the Cryſtalline is three times denſer than the Vitreous, and that the Vitreous is three times denſer than the Aqueous. But the learned Dr. ROBERTSON has informed us, that, upon weighing theſe Humours in a hydroſtatical Balance, he found, that the ſpecific Gravities of the aqueous and vitreous Humours were very nearly equal, and each much the ſame with that of Water; and that the ſpecific Gravity of the Cryſtalline did not exceed the ſpecific Gravity of the others in a greater proportion than that of about 11 to 10; for the mean ſpecific Gravities of five cryſtalline Humours of Oxen's Eyes, and of three cryſtalline Humours of Sheep's Eyes, were 11134 and 11033, the ſpecific Gravity of Water being 10000, and the Mean of theſe Means is 11083; which may therefore be preſumed to be the ſpecific Weight of the human Cryſtalline, and, of conſequence, is to that of the other Humours, nearly as 11 to 10.

§ 9. Whence it follows, that the Cryſtalline is not of ſuch great Uſe in bringing the Rays together, and thereby forming on the *Retina* the Pictures of outward Objects, as it was commonly thought to be by optical

Writers; for tho' in Shape it reſembles a double convex *Lens*, and on that account is fitted to make the Rays converge; yet, for as much as it is ſituated between two Humours, which are nearly of the ſame Denſity with itſelf, it can have but little Force on the Particles of Light; for they are found by Experience to be refracted very little in paſſing out of one *Medium* into another, when the Difference in the Denſities of the *Mediums* is but ſmall. From this we may ſee the Reaſon why the Sight continues after the Operation of the Cataract, in which the Cryſtalline is depreſſed or extracted, and why a convex Glaſs is ſufficient to ſupply the little Refraction that is wanting in the Eye, from the want of this Humour.

§ 10. We may from this alſo ſee, how the Sight may be recovered again, after that all the Humours, the Cryſtalline and Vitreous, as well as the Aqueous, have been expreſſed by a Wound made in the *Cornea*; for, if theſe Humours can be expreſſed without hurting the *Retina*, or immediate Organ of Sight, Nature cures the Wound, and again reſtores the aqueous Humour, ſo as to fill the whole Globe, and reſtore the Eye to its former Turgency; by which means the Light will be as much refracted as in an Eye that has had the Cryſtalline depreſſed in the Operation of the Cataract; and conſequently the Eye muſt again recover its Sight.

That Geeſe and Hens do thus recover their Sight, after that all the Humours have been ſqueezed out by a Wound in the *Cornea*, is manifeſt, from the Experiments of BURRHUS and SCRIVERIUS formerly mentioned; and the ſame Thing is alſo confirmed by the learned KIRKRINGIUS; for, in his *Spicelegium Anatomicum* (*Obſerv.* c.) he tells us, that, without any Aſſiſtance from BURRHUS, or any Body elſe, he of himſelf, had at laſt, after many fruitleſs Experiments, fallen on a Way of reſtoring the Sight of any Animal, after that the whole Humours had been ſqueezed out of the Eye by a Wound made in the *Cornea*; and adds, that, for Trial's ſake, he had repeated the Experiment three times ſucceſſively on the ſame Dog, and had as often cured him, and reſtored his Sight. He indeed attributes the Cure to his Medicine, which he therefore chuſes to conceal, and only tells us, that it is neither made of *Celendine*, nor of the Vitriol of *Mars*, and that he had no Hint of it from BURRHUS, or any Body elſe, but that it was intirely his own Diſcovery. But this Medicine does not appear to have had ſo deep a Share in the Cure as KIRKRINGIUS imagined; for, as has been before obſerved, SCRIVERIUS performed the like Cure upon a Gooſe, a

Cock, and a Hen, without the Aſſiſtance of any Medicine whatever; and if the ſame Thing does not happen to Man, this muſt proceed from the Hurt done to the Eye itſelf, and eſpecially to the *Retina*, and not from the Want of theſe Humours which may be ſupplied by an Accumulation of the aqueous Humour; for Men do not recover of Hurts ſo eaſily and fully as other Creatures do: If they did, they might alſo recover their Sight after having loſt the whole Humours of the Eye; for the aqueous Humour, by being accumulated, could in them ſupply the Want of theſe Humours, as well as in other Creatures.

§ 11. To what has been ſaid concerning the ſmall Degree of Denſity and ſpecific Weight of the Cryſtalline above that of the other Humours, it may be objected, that MAITRE-JEAN found, that this Humour did not only deſcend to the Bottom of Water as quickly as a Stone, but likewiſe deſcended in like Manner when thrown into *Aqua Fortis* and Spirit of Vitriol; from which he concludes, that it is a very denſe and heavy Body (*Malad. de l'Oeil, cap.* xi.)

But it would appear, from what Mr. PETIT has obſerved, (*Mem. de l'Acad. ann.* 1730), that MAITRE-JEAN's Experiments were not performed with ſufficient Accuracy; for tho' PETIT obſerved, that the Cryſtalline of an

Ox fell immediately to the Bottom of Spirit of Vitriol, yet the human Cryſtalline floated in it, and did not deſcend till next Day that its ſpecific Weight was ſufficiently increaſed by the Action of the acid Spirit: He likewiſe found, that the Cryſtallines both of Men and Oxen floated, not only in plane Spirit of Nitre and Spirit of Salt, but alſo in dulcified Spirit of Salt, and in Spirit of Nitre mixed with an equal Quantity of common Water, tho' in this Mixture they afterwards fell to the Bottom, by having their ſpecific Weight increaſed: That of an Ox, in an hour and a Half, but that of a Man, not till next day. And this, without further Reaſoning, I think ſufficient to vindicate Dr. ROBERTSON's accurate Experiments, in which no leſs than eight Cryſtallines were weighed in a hydroſtatical Balance, from any Suſpicion of Miſtake that may ariſe from what has been noticed from MAITRE-JEAN.

§ 12. It is remarkable, that this *Lens* has no viſible Attachment or Communication with any Part of the Body, but is kept in its Place by Means of its Membrane or Capſule, with which nevertheleſs it has not the leaſt Connection. This Capſule has always a little Water in it; in ſome Creatures more, in others leſs, which ſerves to nouriſh the Cryſtalline, to preſerve its Tranſparency, and keep it from adhering to its Capſule; whence this Humour drops out of itſelf ſo ſoon as its Capſule is opened, as has been obſerved by MAITRE-JEAN, Dr. PETIT, and others; who therefore ſcruple not to affirm, that, of all the Parts of our Body, the Cryſtalline is the only one that has no Continuity or Connection with the Parts adjacent, by any Fibre, Blood-veſſel or Nerve. And, indeed, was there any ſuch Connection, it could not fail being obſerved, eſpecially in large Animals, ſuch as Horſes and large Fiſhes; for the larger the Animal is, there is, generally ſpeaking, the more of this watry Humour ſurrounding the Cryſtalline; by means of which this Connection would be the more eaſily diſcovered. Its Quantity, in the Eye of a Man, is indeed but ſmall; it does not commonly much exceed Half a Grain. But in the Eye of a Bull-dog, it weighs one Grain and a Half; in Sheep, two Grains; in Oxen, four Grains; and in Horſes, no leſs than twelve Grains; as PETIT has obſerved (*Mem. de l'Acad. ann.* 1730); and yet no Connection has ever been found in any Animal, not even in Oxen, Horſes, and large Fiſhes, where ſo much of this Liquor is found.

If there were any Veſſels which paſſed from the Capſule to the Cryſtalline, RUYSCH's ſubtile Injections muſt have diſcovered them. But we find he could never go further than the Capſule, and that only by puſhing forward the

Blood in its Veſſels by the ceraceous Matter, from which they became conſpicuous, tho' the ceraceous Matter itſelf could never be made to enter them, (RUYSCH *Theſaur. Anat.* 2. *p.* 37.) Dr. PETIT alſo made Injections into the Eyes, and afterwards diſſected them with the greateſt Care; but he could never, by this or any other Method, find the ſmalleſt Communication or Connexion betwixt the Capſule and the Cryſtalline in any Animal, tho' he was at great Pains to diſcover it; he therefore is very poſitive that there is no ſuch Thing, (*Mem. de l'Acad. ann.* 1730). And it is incumbent on thoſe who maintain the contrary, to ſhew ſome ſuch Connection, or Attachment, at leaſt in ſome one Creature or other, before that they can expect we ſhould believe them. I know, that HOVIUS pretends to ſhew us, in his Figures, the injected Veſſels of the Cryſtalline; but, by a critical Examination of what he ſays on that Head, it appears that theſe Veſſels do not belong to the Cryſtalline, but are either the Veſſels of the Capſule, or imaginary ones.

§ 13. As to what concerns the Uſe of this Capſule, it is three-fold:

1*ſt*, By being attached to the vitreous Humour, it keeps the Cryſtalline fixed in its Place; whence it is, that when this Membrane is torn by a Stroak on the Eye, as ſometimes happens, the Cryſtalline drops out of its

Capſule, and applies itſelf to the poſterior Part of the *Uvea*, where it does not remain long without becoming opaque, by being ſoked in the aqueous Humour; for the aqueous Humour differs from the cryſtalline Liquor contained in the Capſule, and has a ſimilar Effect to that of common Water, in which, if a Cryſtalline be ſteeped, it ſoon ſwells by imbibing the Water which diſranges its Subſtance, and renders it opaque.

2*dly*, This Capſule ſeparates the cryſtalline from the aqueous Humour, and of conſequence preſerves its Tranſparency; which would ſoon be deſtroyed, had the aqueous Humour a free Acceſs to it.

3*dly*, By its Veſſels it furniſhes that cryſtalline Liquor which is ſent into its Cavity, for nouriſhing the Cryſtalline, and for moiſtening it and preſerving its Tranſparency.

That the Cryſtalline has a kind of vegetative Life, and draws Nouriſhment from this Liquor, is evident, from its having no Communication or Connection with any of the neighbouring Parts, from which it can derive any Nouriſhment; and that this Liquor keeps it moiſt and tranſparent, is evident from its becoming dry, hard and opaque, when this Liquor is wanting. This is an Accident that ſometimes happens in conſequence of a violent Inflammation in the inward Parts of the Eye, whereby the Veſſels of the Ciliary Circle are deſtroyed; for ſince theſe Veſſels furniſh not only the aqueous Humour, but alſo the Liquor contained in the Capſule of the Cryſtalline, the Cryſtalline, for Want of this Liquor to moiſten and nouriſh it, becomes dry, hard and opaque, much as when it is taken out of the Eye and dried; and for the ſame Reaſon, it alſo adheres to its Capſule. And if, at the ſame time, the aqueous Humour is not ſupplied in proportion as it is abſorbed and diſſipated, the Membranes of the Eye will contract, and the Cryſtalline will be puſhed forwards, where the Reſiſtance is leaſt, ſo as to reſt upon the *Uvea*, to which it ſoon becomes adherent, as Experience ſhews.

CHAP. XII.

Of the Vitreous Humour.

SECT. I. THE vitreous Humour is of a middle Conſiſtence betwixt that of the aqueous and cryſtalline Humours. It hath a great Reſemblance to the White of an Egg, but is more tranſparent and ſomewhat thicker. It is the largeſt of all the Humours of the Eye, and fills the whole Back-part of the Globe, from the Cryſtalline and the *Ligamentum Ciliare* to the *Retina.* It adheres pretty cloſely to the Edge of the *Choroides,* where, in going forwards, it forms the *Uvea,* and ſeems to receive its Coat from ſome of its Fibres reflected inwards at that Place; where alſo ſome black Filaments ariſe, which are ſpread upon its Fore-part behind the *Ligamentum Ciliare*; theſe Filaments are all along adherent to its Membrane: Some Anatomiſts have miſtaken and deſcribed them for the *Ligamentum Ciliare* itſelf.

§ 2. I obſerved before, that, in the Middle of its Fore-part, there is a ſmall Dimple or Concavity, in which the whole poſterior Convexity of the Cryſtalline is received: The reſt of its Fore-part round this Concavity forms a convex *Annulus* or Ring, in croſſing which the Fibres of the *Ligamentum Ciliare* are inflected, and form an Arch, as they proceed from their Origin in the Ciliary Circle to their Inſertion in the Edge of the Cryſtalline; for, as theſe Fibres are contiguous to the vitreous Humour in their whole Courſe, they muſt neceſſarily form an Arch ſimilar to that of the *Annulus* of the vitreous Humour over which they paſs.

By this Diſpoſition the ciliary Ligament is excellently fitted for changing the Situation of the Cryſtalline, and removing it to a greater Diſtance from the *Retina*, when we look at near Objects; for, when it contracts, it will not only draw the Cryſtalline forewards, but, by compreſſing the *Annulus* of the vitreous Humour lying behind it, it will make this Humour riſe in the Middle behind the Cryſtalline, by which the Cryſtalline will be puſhed forewards farther from the *Retina*. But this will fall to be explained hereafter, in treating of the Change made in our Eyes for enabling us to ſee at different Diſtances; to which therefore, to avoid Repetitions, I muſt refer the Reader.

§ 3. The vitreous Humour, as well as the Cryſtalline, ſeems to conſiſt of ſolid Parts, which contain an Humour much like the aqueous Humour: But, they are ſo delicate and tranſparent, that it is impoſſible to diſtinguiſh them from the Humour they contain; and therefore it is neceſſary that ſome Experiments be made for demonſtrating their Exiſtance, and for enabling us to form ſome probable Opinion with regard to their Diſpoſition.

Exper. I. Take the vitreous Humour of any Animal newly killed, and having laid it upon a Plate, you ſhall obſerve that it takes a round flat Figure, and ſweats out from its whole Surface a thin clear *Serum*, much like the aqueous Humour, in ſo much that whatever Part of this Humour you ſhall touch with your Finger, you ſhall always find it wetted with this *Serum*. As the Diſcharge of this *Serum* is very ſlow, this Humour continues a long while without being ſenſibly diminiſhed; but, if it be pierced with a Pin, or the Point of a Scalpel, in ſeveral Places, the *Serum* will run out more abundantly, and the Humour will appear more diminiſhed where the Openings are made, than at ſome Diſtance from them; and if the Perforations are made pretty large, and in ſufficient Number, the Humour will ſoon be evacuated of the greateſt Part of the *Serum* it contained, and will proportionably diminiſh in Bulk.

Exper. II. Take another of thoſe Humours, and preſs it betwixt your Fingers, and you ſhall be very ſenſible of ſomething which breaks within; which can be nothing but ſome of its ſolid Fibres; and if you pierce it in ſeveral Places, as above, and continue to preſs it gently, the *Serum* therein contained will be more abundantly expreſſed, and what remains will be more ſolid and firm.

Exper. III. Take a third vitreous Humour, and throw it into Water almoſt boiling, and you ſhall obſerve, that, as it warms, it diminiſhes in Bulk, becomes round, and ſomewhat more ſolid; and if you make the Water boil, it will ſtill diminiſh more and more in Bulk, and become more and more ſolid, ſtill preſerving its Roundneſs, till at laſt it be no bigger than a ſmall Pea, but exceeding ſolid.

§ 4. From theſe Experiments, it ſeems reaſonable to conclude:

1*ſt.* That the Membrane covering the vitreous Humour is porous in all its Parts; for, were it not porous, it would not allow the watry *Serum* to ſweat thro' it, when the vitreous Humour is laid upon a Plate, nor would this Humour diminiſh ſo quickly in Bulk when boiled in Water; for this Diminution made in its Bulk by boiling, muſt proceed from the Expulſion of this watry *Serum*; which therefore muſt find a Paſſage thro' the Pores of this Membrane.

2*dly*, That the vitreous Humour, beſides its membranous Covering, has other Membranes or membranous Fibres, which enter its Compoſition, and which, it is probable, are Productions of its membranous Covering, or at leaſt are attached to it: Whence it is, that this Humour becomes round and hard, when its Fibres are made to contract by the Boiling-water, and that, when it is preſſed by the Fingers, ſomething is felt to break within.

3*dly* That theſe Membranes or membranous Fibres ought to form a Number of little Cellules which contain the watry *Serum*; for, were this *Serum* contained only in the Interſtices betwixt the Fibres, without any cellular Work, it would preſently run out, upon opening the Membrane covering the vitreous Humour.

4*thly*, and *laſtly*, That theſe Cellules communicate with one another by ſmall Holes or Canals like the *Membrana Adipoſa*; whence it is, that when the membranous Covering of this Humour is pierced, theſe Cellules empty themſelves ſucceſſively, and that the watry *Serum* runs out more abundantly when this Humour is gently ſqueezed.

From what hath been ſaid, I think it is more than probable, that this Part is not a congealed Humour, as the greateſt Part of Authors have taught, but that it is compoſed of Solids and Fluids, like the other Parts of our Body, and is nouriſhed by its own proper Veſſels; of which RUYSCH, in a Whale, has obſerved ſeveral Branches ſpread upon its Tunicle, as well as upon the Tunicle of the Cryſtalline.

§ 5. Dr. BRIGGS ſays, that this Humour is about three times denſer than the Aqueous: In which he is greatly miſtaken; for, if it is thrown into Water, it floats therein much like

Wax, and therefore cannot differ much from the aqueous Humour in Denſity. And this is confirmed by the more accurate Experiments of Dr. ROBERTSON, who, having weighed the Humours of the Eye in a hydroſtatical Balance, found, that the ſpecific Gravities of the aqueous and vitreous Humours were very nearly equal, and each much the ſame with that of Water; as has been before noticed. And this is further confirmed by the accurate Mr. HAUKSBEE, who, in his Phyſico-mechanical Experiments, has given us a Table of the ſpecific Gravities, Angles of Obſervation, and *Ratio's* of Refraction of ſeveral Fluids, by which it appears, that the Angle of Obſervation and the *Ratio* of Refraction, n the vitreous Humour of an Oxe's Eye, are the ſame as in Water; whence their Denſities muſt alſo be equal; for, *cæteris paribus*, the refractive Power of Bodies is as their Denſities; as has been before obſerved.

CHAP. XIII.

Of the Ligamentum Ciliare.

THE laſt Thing to be conſidered in the Structure of our Eyes is the *Ligamentum Ciliare*. But having, in the preceeding

Chapter, had occaſion to take Notice of the Arch which it forms in paſſing over the convex *Annulus* of the vitreous Humour, I have nothing further I need to remark, but what has been before obſerved in the general Idea of the Eye, which I ſhall not now repeat, but ſhall rather take notice of another remarkable Part, the *Marſupium Nigrum*, which is peculiar to Birds, and is never to be found in other animals.

C H A P. XIV.

Of the Marſupium Nigrum, *of Black Purſe, peculiar to Birds.*

SECT. I. THIS Part, which is peculiar to Birds, and never to be found in other Animals, takes its name from its Form, being nothing but a Membrane in Form of a Purſe, which ariſes from the Entry of the optic Nerve, and paſſes thro' the vitreous Humour to its Inſertion in that Part of the Edge of the Cryſtalline which is next the great *Canthus*. Thus it is deſcribed by the *French* Academiſts, and, in particular, by Monſ. PERRAULT, in his *Mechanique du Animaux*;

maux; from whom I have cauſed it to be copied, at *Fig*. 7. PLATE I. which repreſents the Half of the Globe of an Oſtrich's Eye; in which A is the cryſtalline Humour, B the optic Nerve, and C the black Purſe attached above to the Cryſtalline, and below to the optic Nerve. But, in ſome Birds, I have found this Membrane of a rhomboidal Figure, agreable to the Account given of it by DERHAM, in his *Phiſico-theology*, and Dr. PETIT, in the *Memoires de l'Academie Royale*, *ann*. 1720.

§ 2. This Membrane is always covered with a black Pigment, which is of a more intenſe Colour than either that of the *Uvea*, or *Choroides*; yet, if it be cleaned and waſhed, it appears to be compoſed of muſcular Fibres not unlike the *Ligamentum Ciliare*; as the learned Monſ. *de la* HIRE long ago obſerved. It is remarkable, that, in proportion as Birds naturally fly more high, and by that Means require a more piercing Sight, this Bag is always more black; for our domeſtic or tame Birds, which either do not fly, or do not fly high, ſuch as Hens, Geeſe, *&c*. have this Part not near ſo black, as Eagles, and other Birds of Prey.

Mr. DERHAM calls this Membrane the *Pecten*, becauſe of its Reſemblance to a Comb in ſome Animals; and has alſo obſerved its Structure to be very like that of the *Ligamentum Ciliare*; and in the Eye of a Magpy, and ſome other Birds, which he examined, he tells us, he could plainly perceive it to be muſculous towards the Bottom.

A TREATISE ON THE EYE, the Manner and *Phænomena* of VISION.

BOOK III.

Of Viſion.

CHAP. I.

Of the Nature and Properties of Light.

HAVING conſidered the beautiful Fabric of the Eye, I may ſay, in a curſory, not accurate, ſtrict Manner, which, conſidering the prodigious Workmanſhip thereof, would have required more Time and Pains than what I could at preſent eaſily beſtow; and beſides, my main Deſign being to explain the Manner and chief *Phænomena* of Viſion, and to lay a Foundation for underſtanding the Nature of the Diſeaſes of the Eye, and the proper Means whereby they may be cured; I thought it ſufficient to give ſuch a general Deſcription of this Organ, as might in ſome Meaſure anſwer thoſe Ends. The next Thing which falls in order to be explained, is the Manner of Viſion, and the Office of the ſeveral Parts of the Eye concerned therein: But all Viſion being performed by means of Light, it is neceſſary that, firſt of all, I ſhould inquire into the Nature and Properties of this ſubtile *Medium*, without the Knowledge of which no Body can either explain Viſion, or account for its *Phænomena*, or rightly underſtand or remedy the Defects thereof, which happen in the Diſeaſes of the Eye.

§ 1. *Firſt*, Then, Light is not a Quality, as ARISTOTLE, and a great many Philoſophers have taught, but a real Subſtance, conſiſting of material Particles, propagated from the Sun and other luminous Bodies.

This ſeems to be evident, from theſe Conſiderations: 1*ſt*, Like all other Bodies, it is progreſſive, and is not propagated in an Inſtant, but ſpends about ſeven or eight Minutes of an Hour in paſſing from the Sun to the Earth. This was firſt obſerved by Mr. ROMER, Profeſſor of Aſtronomy to the late King of *France*, and then by others, by Means of the Eclipſes of the Satellites of *Jupiter*: For theſe Eclipſes, when the Earth is between the Sun and *Jupiter*, happen about ſeven or eight Minutes ſooner than they ought to do by the Tables; and when the Earth is beyond the Sun, they happen about ſeven or eight Minutes later than they ought to do; the Reaſon being, That the Light of the Satellites has further to go, in the latter Caſe than in the former, by the Diameter of the Earth's Orbit.

2*dly*, It may be ſtopt or reſiſted in its Paſſage from one Place to another, by the Interpoſition of an opaque Body, as other Fluids are ſtopt in their Courſes by the Oppoſition of any ſolid Body.

3*dly*, Like all other Bodies in Motion, it may be turned out of its rectilinear Courſe, may have the Determination of its Motion changed by Reflection or Refraction, and may be congregated within a narrower, or ſcattered thro' a larger Space; as is evident from reflecting *Specula*, and refracting Burning-glaſſes.

4*thly*, It acts upon the Organs of Animals, and upon all other Bodies as other fluid Subſtances do, by ſtriking upon them with a determined Force, by communicating a certain Degree of Motion to them, by ſeparating their component

Parts, and putting them in Motion: All theſe Effects we daily ſee.

5thly, The Parts of Light are endowed with various original Colours; ſome are red, others blue; others yellow, and ſome green, *&c.* as NEWTON has demonſtrated, and may be ſeen by a Priſm applied to the Hole of a darkened Room, thro' which the Sun ſhines. Now, ſince Colours are the Qualities of Light, having its Rays for their intire and immediate Subject, how can we think thoſe Rays Qualities alſo, unleſs one Quality may be the Subject of and ſuſtain another, which is in effect to call it a Subſtance? We ſhould not know Bodies for Subſtances, were it not for their ſenſible Qualities; and the principal of thoſe being now found due to Light, we have as good Reaſon to believe that to be a Subſtance alſo.

6thly, and *laſtly*, It may be confined and ſhut up in determined Spaces, like other Fluids, and the Bodies wherein it is thus confined are frequently found to increaſe in Weight from the Addition of the material Subſtance of which it conſiſts. This has been proved by the famous BOYLE from actual Experiments on Silver, Copper, Tin, Lead, Spelter, Iron, and other Bodies expoſed, both naked and cloſely ſhut up, to Fire; all which were conſtantly found to receive an Increment of

Weight. (See BOYLE's *Exper. to make Fire and Flame ponderable*). After him the ſame Experiments have been repeated by others, both of the *French* and *Engliſh* philoſophic Societies, with the ſame Succeſs. And this holds true, not only when Bodies are expoſed to our common Fires, but likewiſe when they are expoſed to the Sun's Heat concentred with Burning-glaſſes, or with concave Mirrors: For, as is to be ſeen in the Memoirs of the *French* Academy, if the *Regulus* of Antimony be placed at a Due Diſtance from the *Focus*, either of a concave *Speculum*, or of TSCHIRNHUSE's Cauſtic Glaſs, it emits Vapours copiouſly; notwithſtanding which, it becomes heavier than before; which muſt proceed, at leaſt in part, from the material Subſtance of the Light united with that of the calcined Antimony. Nor needs this be thought ſtrange or wonderful, ſeeing NEWTON has ſhewed, in a Multitude of ſtriking Inſtances, that the changing of groſs Bodies into Light, and Light into groſs Bodies, is very conformable to the Courſe of Nature, which ſeems delighted with Tranſmutations, (*Optics*, *Quer.* 30.). Now, all the foreſaid Properties are the Properties of Bodies, and can belong to nothing but material Subſtance; whence we conclude, that Light is a Body.

§ 2. *Secondly*, The material Particles of which Light conſiſts, are emitted from the luminous Bodies themſelves, by the powerful Vibrations of their ſmalleſt Parts.

For, if, with the Famous DES CARTES, you ſuppoſe that all that Space betwixt us and the Sun, and other luminous Bodies is filled with a *Materia Subtilis*, and that Light conſiſts in the Preſſion or Motion of this Fluid, each Particle next the Sun or luminous Body preſſing or moving the next adjacent one, and that again the next, and ſo on, till thoſe next our Eyes receive alſo the ſame Preſſion or Motion; then it would follow, that Light would always bend into the Shadow; and the Shade made by the Interpoſition of any opaque Body, betwixt it and the luminous Body, would likewiſe be illuminated by the Light, which, paſſing by the Edges of the Obſtacle, would bend inwards. For Preſſion or Motion cannot be propagated in a Fluid in right Lines beyond an Obſtacle which Stops Part of the Motion, but will bend and ſpread every Way into the quieſcent *Medium* which lies beyond the Obſtacle. Thus Gravity tends downwards; but the Preſſure of Water ariſing from Gravity, tends every way with equal Force, and is propagated as readily, and with as much Force Side-ways, as downwards, and thro' crooked Paſſages as thro' Streight ones. The Waves on the Surface of ſtagnating Water paſſing by the Sides of a broad Obſtacle which ſtops Part of them, bend afterwards, and dilate themſelves gradually into the quiet Water behind the Obſtacle. The Waves, Pulſes, or Vibrations of the Air, wherein ſounds conſiſt, bend manifeſtly, tho' not ſo much as the Waves of Water; for a Bell, or a Cannon, may be heard beyond a Hill, which intercepts the Sight of the ſounding Body; and Sounds are propagated as readily thro' crooked Pipes, as thro' ſtreight ones: But Light is never known to follow crooked Paſſages, nor to bend into the Shadow. For the fixed Stars, by the Interpoſition of any of the Planets, ceaſe to be ſeen, and ſo do the Parts of the Sun by the Interpoſition of the Moon, Mercury or Venus, becauſe the Eye is then placed in the Shade made by theſe interpoſed Bodies; which would not happen, if Light conſiſted in Preſſion or Motion excited in the fluid Body of DES CARTES's ſecond Element, or any other *Materia ſubtilis*; and therefore it muſt be allowed, that it conſiſts of material Particles emitted from luminous Bodies by the powerful Vibrations of their ſmalleſt Parts, and propagated from thence to us, and all round in ſtreight Lines, like Lines drawn from the Centre of a Globe to the Circumference.

§ 3. A *third* Property of Light is, that its Particles are extremely ſmall. For,

Firſt, They paſs thro' all Bodies that are pervious, ſuch as Cryſtals, Glaſſes, ſeveral Gems, and almoſt all Fluids, but Mercury; and it freely paſſes where no other Fluid, how thin ſoever, can enter; and yet no Eye, however aſſiſted, has been able to diſcover or diſtinguiſh the Parts of the groſſeſt Fluid.

Secondly, If a common Tallow-Candle be lighted, and ſet by Night on the Top of a high Tower, it may be ſeen all round at the Diſtance of half a Mile from the Tower: Wherefore, there is no Place within a Sphere of a Mile Diameter, in which the Eye can be placed, where it will not receive ſome Rays of Light from this little Flame. All thoſe Rays were before concentred in the Flame, which, as it is exceeding ſmall in reſpect of the Sphere that is illuminated, it proves the immenſe Subtility of the Rays of Light.

Thirdly, Were not the Particles of Matter compoſing Light exceeding ſmall, they would claſh upon one another, where the Rays croſs, and mutually oppoſe each other, in their progreſſive Motion. But this never happens; for we find, that innumerable different Spheres of Light within our Horizon may be propagated from their ſeveral luminous Centres without interfering. How many Millions of Candles and Flambeaux may we ſee ſending out their Tides of Light without claſhing upon one another? Which argues both the Smallneſs of the Parts of Light, and the Largeneſs of the void Interſtices between the Particles of Air and other Bodies tranſmitting it. If a very ſmall Hole be made in the Window-ſhut of a dark Chamber, wherein no Light enters but by the ſmall Hole; and if without the Chamber be ſet innumerable luminous Objects of about the ſame Height with the Hole, and at an ordinary Diſtance from it, the Light proceeding from every one of thoſe Objects will be propagated thro' this ſmall Hole without interfering. This will appear, by applying a dark Object within the Chamber directly oppoſite to the Hole; for the Light of all theſe luminous Bodies without the Chamber, will, thro' the Hole, be received upon the dark Body the ſame Way, as if there had been only one luminous Body. Now, it is impoſſible that ſo many different Streams of Light could be tranſmitted thro' ſo ſmall a Hole, were not the Particles of Light extremely ſmall. In like manner, if a ſmall Hole be made with a Needle in a Paper, a Spectator lying on his Back, and looking thro' this Hole, may ſee all the Objects in the celeſtial Hemiſphere; and when he ſtands upright, he may ſee a fourth Part of the Heavens, together with all the Bodies that are before him on the Ground; ſo that an innumerable Quantity of Rays, either emitted or reflected from Objects, paſs thro' this Hole, without interfering or diſturbing one another's Motions; which ſhews the extreme Subtility of Light, ſuch as is not eaſy to be comprehended by the utmoſt Streatch of the human Mind.

Fourthly, Were not the Particles of Light extremely ſmall, being extremely ſwift, (*i. e.* more than a Million and a half of times ſwifter than a Cannon-bullet continuing in its greateſt Velocity, (as ſhall be preſently ſhown) they would have a vaſt Force, and thereby would pierce all Kinds of ſolid Bodies with almoſt as great Facility as they do Vacuities; whereas, we ſee Light regularly reflected from ſome Bodies.

§ 4. *Fourthly*, Another thing remarkable in Light, is the Swiftneſs of its Motion.

How extremely ſwift the Particles of Light are, we may gather from the forementioned Experiment of Mr. ROMER, whereby he demonſtrates that the Streams of Light paſs from the Sun to our Earth in about eight Minutes, and, according to the Obſervations of MERSENNUS, a Bullet ſhot out of a great Gun flies 92 Fathoms in a ſecond of Time, (*Vid. Merſen. Balliſt.*) which is equal to 589 ½ Feet *Engliſh*; and, according to the Computation of Mr. HUYGENS, in his *Coſmotheoros*, it would be 25 Years in paſſing from the Earth to the Sun. Now, the *Via percurſa* being the ſame in both, the Velocities will be reciprocally as the Times, *i. e.* the Velocity of Light will be to that of a Cannon-bullet perſiſting in its greateſt Swiftneſs, as 25 Years is to 8 Minutes, or as 1,642500 to 1; ſo that the Velocity with which the Particles of Light paſs, will be more than a Million and a half of times ſwifter than a Cannon-bullet. Moreover, the Diſtance betwixt the Sun and us, according to the moſt accurate Obſervations of the lateſt Aſtronomers, being 70 Millions of Miles, the Light muſt run at leaſt 145833 Miles in a ſecond of Time. But Sound goes but 1142 Feet in a ſecond; and there being 5000 Feet in a Mile, the Velocity of Light will exceed the Velocity of Sound in the proportion of about 647342 to 1. This is a prodigious and almoſt an incredible Velocity, but the extraordinary Effects of Light and Heat ſeem to require it all: We ſee how powerfully it acts, (being congregated) upon the moſt compact ſolid Bodies, and we never perceive any Diminution of its Force from which we can ſuſpect any Abatement of its Velocity.

§ 5. A *Fifth* Property of Light is, its Reflexibility, or its Diſpoſition to be turned back into the ſame *Medium* by any other *Medium* upon whoſe Surface it falls. And in this it obſerves the ſame Law that other Bodies do in their Reflections, *viz.* the Angle of Reflection is always equal to the Angle of Incidence.

The Truth of this is eſtabliſhed by Multitudes of Experiments. The following one is very eaſy.—Into a very dark Chamber, thro' a ſmall Hole made in the Window-ſhut, let a Beam of the Sun's Light paſs; and, upon the Floor where this Beam falls, place a Looking-glaſs; then fill the Room with Duſt, or Smoak, by which means the Beam will become very viſible in its whole Courſe, and you ſhall obſerve, that this Beam ſhall be reflected back into the Air by the Looking-glaſs; and that the Angle of Reflection is equal to the Angle of Incidence.

ILLUSTRATION. Let B (*Fig.* 8. PLATE I.) be the Hole in the Window-ſhut; ABC the Beam of the Sun's Light falling on the Looking-glaſs GCF at C. This Beam ſhall, after its Incidence at C, be reflected back in the Line CD.

From the Looking-glaſs at the Point of Incidence C, raiſe the Perpendicular CE; the Angle ACE, which the incident Beam AC makes with the Perpendicular CE, is the Angle of Incidence; and the Angle DCE, which the reflected Beam CD makes with the ſame Perpendicular CE, is the Angle of Reflection. Now, theſe Angles, upon meaſuring them, are always found equal, with whatever Obliquity the Rays fall upon the Looking-glaſs or any other poliſhed reflecting Body.

There are many other ways of meaſuring the Angles of Incidence and Reflection; by all which they are conſtantly found equal. We have here made choice of this Way as the moſt eaſy; our Deſign being not to give a Syſtem of Optics, but to explain, in the moſt ſimple Manner, ſuch of the fundamental Properties of Light as may be of Uſe to underſtand what followeth. The following Method is alſo very ſimple, and eaſy to be practiſed.

Upon the Looking-glaſs DE (PLATE II. *Fig.* 9.) place a ſemicircular Plane FIG, ſo as its Centre may be in B, and its Surface may be perpendicular to the Looking-glaſs: This done, from the Centre B raiſe the Perpendicular BI, and make the Arch IC equal to IA. In C, or any other Point of the Line BC produced, place a ſmall Object; and in A, or any other Point of the Line BA produced, place the Eye; the Object ſhall be ſeen by the Ray BA reflected by the Looking-glaſs at B; becauſe the Angle of Incidence CBI is equal to the Angle of Reflection ABI. But if the Point of the Looking-glaſs B be covered, the Eye at A will no more ſee the Object at C; becauſe none of the Rays which come therefrom can, by the other Parts of the Looking-glaſs, be reflected to the Eye at A.

§ 6. This Reflexibility of Light is a Thing that muſt have been pretty well known to many of the Antients; for tho' they had but little Knowledge of Dioptrics, yet no one denies them the Knowledge of Catoptrics, which they cultivated long before Dioptrics were handled. EUCLID himſelf wrote a Book on the Elements of Optics and Catoptrics, which is to be found in GREGORY's Edition of Euclid's Works, tho' there are many learned Men who will not allow that EUCLID the Geometer was the Author of this Book, becauſe of ſome Blunders that are in it, which EUCLID the Geometer is not thought to have been capable of. ARCHIMEDES alſo wrote a Book, as it is ſaid, *de Speculis Uſtoreis parabolicis*. But it has never yet ſeen the Light.

§ 7. There is one Thing relating to the Reflection of Light, which at firſt View ſeems to be contrary to what has been proved of the Angle of Reflection being always equal to the Angle of Incidence; and that is, that there is no reflecting Body, how well ſoever poliſhed, but, beſides the Light which it reflects regularly, ſcatters every way irregularly a conſiderable Quantity of Light; by means of which the Surface of the beſt poliſhed Looking-glaſs, when illuminated in a dark Room by a Beam of the Sun's Light, let in at a Hole in the Window, may be eaſily ſeen in all Poſitions of the Eye.

But this does not at all prove, that in any Caſe the Angles of Incidence and Reflection are of different Magnitudes; for, however well Bodies may ſeem poliſhed, yet their Surfaces are doubtleſs full of Inequalities all over, by which means the Rays of Light, by every ſenſible Point of the Surface, are reflected every way; for, in poliſhing Glaſs with Sand, Putty or *Tripoli*, it is not to be imagined that theſe Subſtances can, by grating and fretting the Glaſs, bring all its leaſt Particles to an accurate Poliſh, ſo that all their Surfaces ſhall be truly plain and look all the ſame Way, ſo as, together, to compoſe one even continued Surface; the ſmaller the Particles of thoſe Subſtances are, the ſmaller will be the Scratches by which they continually fret and wear away the Glaſs, until it be poliſhed. But, be they never ſo ſmall, they can wear away the Glaſs no other ways than by grating and ſcratching it, and breaking the Protuberances; and therefore poliſh it no otherwiſe than by bringing its Roughneſs to a very fine Grain, ſo that the Scratches and Frettings of the Surface become too ſmall to be viſible. Now, the Surfaces of all Bodies, being more or leſs rough or unequal, may be conceived as made up of an innumerable Quantity of ſmall Planes, which, in all ſenſible Points, are directed every way; or they may be conceived as covered with an innumerable Quantity of ſmall Hemiſpheres, upon which the Light falling, will be reflected every way, ſo that the Body will be viſible in all Poſitions of the Eye.

That this is true, we deduce from the Reflection of Light from poliſhed Surfaces; for the better the Poliſh be, and the ſmaller the Grain is with which they are poliſhed, the more Light will be regularly reflected, and the leſs ſcattered. Hence it is, that a well-poliſhed Looking-glaſs ſcatters only a very faint Light when illuminated in a dark Room by a Beam of the Sun's Light, and therefore is but obſcurely ſeen, except when the Eye is placed in the reflected Beam; and even from the Surface of Bodies which are not at all poliſhed, the Light is moſtly reflected that Way that it would be all reflected were it poſſible to bring its Surface to a perfect and accurate Poliſh; and therefore the ſcattered Light does not at all deſtroy what has been above proved of the Equality of the Angles of Incidence and Reflection, but excellently accounts for Bodies being viſible in all Poſitions of the Eye; for, that Bodies might not be inviſible in any

Poſition of the Eye, it was abſolutely neceſſary that their Surfaces ſhould be rough and unequal, ſo that from every viſible Point the Light might be ſcattered every way, like Rays drawn from the Centre to the Circumference, and ſo might fall upon the Eye in every Poſition or Situation.

§ 8. A *Sixth* Property of Light is its Refrangibility, or Diſpoſition to be refracted or turned out of its ſtreight Courſe, in paſſing obliquely out of one tranſparent *Medium* into another of different Denſity.

§ 9. This Refraction of Light, at the Surfaces of tranſparent Bodies, is a Thing that was taken notice of by the Antients; for ARISTOTLE has a Problem concerning the apparent Curvity of an Oar in Water; and ARCHIMEDES, that famous Geometrician, is ſaid to have written a Book about the Appearance of a Ring or Circle under Water, in which no doubt he conſidered the Refraction of the Rays, and the Fallacy of Sight thence ariſing. But it does not appear, that the Antients made any Progreſs in Dioptrics, or had any Knowledge of Optic-glaſſes; for their moſt learned and inquiſitive Philoſophers have not the leaſt Hint of them in their Writings; and doubtleſs, a Contrivance of that univerſal Uſe, beneficial to all old Men, both in reading and writing, could never have been ſo concealed, as that not the leaſt Footſteps thereof ſhould remain to Poſterity. The only Relief they had for their decayed Sights, were certain *Collyria* or Eye-ſalves; and, when theſe failed them, they were left almoſt in the dark for minute and near Objects.

We hear indeed of mighty Stories of ARCHIMEDES burning the Ships of MARCELLUS at a great Diſtance from the Walls of *Syracuſe*. But whether the Matter of Fact be true or falſe (as I am very inclinable to believe it falſe,) yet there is no mention of his performing this admirable Effect by Optic-glaſes. Perhaps, if there were any ſuch thing done at all, it was performed by concave *Speculums;* for no body denies the Antients the Knowledge of Catoptrics, and ARCHIMEDES himſelf is ſaid to have writ a Book *de Speculis Uſtoriis Parabolicis*; as has been before obſerved.

§ 10. And as Optic-glaſſes were unknown to the Antients, ſo they knew not the exact Laws of Refraction. ALHAZEN the *Arabian*, who wrote a large Volume on Optics, about the Year 1100, in which he makes uſe of the more antient Writers, and eſpecially the ten Books of PTOLOMY, which are now loſt; and after him VITELLIO the *Polander*, who, finding ALHAZEN's Demonſtrations very tedious and intricate, wrote a Book on the ſame Subject about 70 Years thereafter; in which he indeed borrows a great deal from ALHAZEN, but is more conciſe in his Demonſtrations, which he builds on Principles taken from APPOLLONIUS, THEODOSIUS, MENELAUS, THEON, PAPPUS, and PROCLUS. Both theſe Authors being ignorant of the exact Laws of Refraction, tell us, that the Angles of Incidence and Refraction are in a given *Ratio*; and thought they had pretty well proved it by Experiments. But this Proportion being found erroneous in large Angles, in which the Error is moſt conſpicuous, the Moderns began to examine the Matter more ſtrictly. The learned KEPLER, among the reſt, made ſeveral Experiments about it, in his *Paralipomena ad* VITELLIONEM, publiſhed in the Year 1604: But he miſſed his Aim. Nevertheleſs, his Conjectures and Attempts became uſeful to others; and, after the Invention of Teleſcopes, the Subject of this Inquiry being thought more valuable than before, was further purſued; and WILLEBRODUS SNELLIUS, after many troubleſom Experiments, was at laſt ſo lucky as to find out the Truth: But ſtill he did not thoroughly comprehend his own Invention. But of this more hereafter.

§ II. That Light is turned out of its ſtreight Courſe, in paſſing out of one *Medium* into another, is a Thing now ſo well known to every Body, that I need not waſte much

Time to prove it. It may be gathered from the following eaſy Experiment:

Take an empty Veſſel, ſuch as a Baſon, and all along the Diameter of its Bottom fix little Marks at a ſmall Diſtance from one another; then, thro' a ſmall Hole in the Window-ſhut of a dark Chamber, let in a Beam of the Sun's Light; where this Beam falls upon the Floor, place your Baſon ſo as its marked Diameter may point towards the Window, and as the Beam of Light may fall on the Mark that is moſt diſtant from the Window. This done, fill the Baſon with Water, and you ſhall obſerve, that the Beam which before fell upon the moſt diſtant Mark, will now, by the refractive Power of the Water, be turned out of its ſtreight Courſe, and fall two, three, or more Marks nearer the Centre of the Baſon.

If you make this Water a little muddy, but not ſo much as to loſe its Tranſparency, which may be eaſily done by dropping into it a few Drops of Milk, or diſſolving therein ſome Grains of *Saccharum Saturni*; and if you raiſe ſome Duſt in the Room, or fill it with Smoak, the Beam of Light will become very viſible, both in its Paſſage thro' the Air and the Water, and you ſhall obſerve very diſtinctly three Beams; that of Incidence, which, in coming thro' the Hole in the Window-ſhut, falls obliquely on the Surface of the Water; that of Reflection from the Surface of the Water, making the Angle of Reflection equal to that of Incidence, and that of Refraction, which, from the Surface of the Water where it is bended, moves in a ſtreight Line to the Bottom of the Baſon.

All things remaining the ſame, if you place a Bit of plain Mirror at the Bottom of the Baſon where the refracted Beam falls, the Beam will thereby be reflected back again thro' the Water, making the Angle of Reflection equal to that of Incidence; and in paſſing out of the Water into the Air, it will be again refracted, or turned out of its ſtreight Courſe.

§ 12. Having thus ſhewn that Light is refracted or turned out of its Way, in paſſing obliquely out of one tranſparent *Medium* into another of different Denſity, I ſhall now inquire into the Laws of Refraction by Experiments; in order to which, it may be proper to premiſe the following Definitions:

Suppoſe that BC (*Fig.* 10. PLATE II.) repreſents the Surface of ſtagnating Water, or any other tranſparent *Medium* denſer than Air, and that A is the Point of Incidence, in which any Ray coming in the Air from F, in the Line FA, is refracted from its right Courſe AK in the Line AG. About the Centre A, with the *Radius* AF, deſcribe the Circle BFCKE; erect upon the Surface of the Water, from the Point of Incidence A, the Perpendicular AD, and produce it downwards to E; and from the Point F, upon the Line AD, let fall the Perpendicular FH; and from the Point G, to the Line AE, let fall the Perpendicular GI.

DEFIN. I. The Angle FAD, which the incident Ray FA contains, with the Perpendicular DA, is the Angle of Incidence.

DEFIN. II. The Line FH is the Sine of the Angle of Incidence FAD.

DEFIN. III. The Angle GAE, which the refracted Ray AG makes, with the Perpendicular AE, is the Angle of Refraction.

DEFIN. IV. The Line GI is the Sine of the Angle of Refraction GAE.

Theſe Definitions being underſtood, it will be no difficult Matter to find out by Experiments the Laws of Refraction. Thus, if the Refraction out of Air into Glaſs be ſought, take a rectangular well-poliſhed Board about two Feet long and about one Foot broad: To the End of which, at Right-angles, join another rectangular Board of the ſame Breadth, but only half a Foot high. This done let a cubical Piece of ſolid Glaſs, whoſe Sides being half a Foot ſquare, are equal to the Height of the ſhort Board, be placed upon the long

Board cloſs to the other; then ſet this Inſtrument upon a Table, or any other horizontal Plane, ſo as when the Sun ſhines the ſhort Board may caſt its Shadow upon the other. By obſerving carefully the Termination of the Shade, both within the Glaſs and without it, you may eaſily find how much the Light is refracted in paſſing out of Air, into Glaſs.

ILLUSTRATION. Let AB (*Fig.* 11. PLATE II.) repreſent the long Board two Feet in Length and about one Foot broad, and let BC repreſent the ſhort Board of the ſame Breadth joined to it at Right-angles at B; and ſuppoſe BCDE a Cube of ſolid Glaſs, which, having its Sides half a Foot ſquare, is equal in Height with the ſhort Board BC.

Now, the Board BC being one Foot broad, and the Glaſs Cube only half a Foot, the Light which paſſes over the upper End of this Board will in part paſs ſtreight forwards towards the other Board, without entering the Glaſs, or ſuffering any Refraction thereby. But the Light which paſſing over the ſame End of the Board falls upon the Glaſs, will, by the refractive Power of the Glaſs, be turned out of its ſtreight Courſe. Let therefore HC repreſent the Sun's Light paſſing by the upper End of the Board C; CF ſhall repreſent the Courſe of the Light which does not fall upon the Glaſs, but moves on in its ſtreight Courſe without ſuffering any Refraction, and F ſhall be the Point where the Shadow BF terminates. In like manner CG ſhall repreſent the Courſe of the Light which, in falling upon the Glaſs at C, is, by its refractive Power, turned out of its ſtreight Courſe, and G ſhall be the Place where the Shadow BG terminates within the Glaſs.

From the Point of Incidence C, raiſe CI perpendicular to the refracting Surface CD; the Angle HCI, which the incident Ray HC makes with the perpendicular IC, is the Angle of Incidence; and the Angle GCB, which the refracted Ray GC makes with the perpendicular BC, is the Angle of Refraction. But the Angle HCI is equal to the Angle FCB, being Angles at the *Vertex*; and therefore if the Line CB be conſidered as the *Radius*, FB ſhall be the Tangent of the Angle of Incidence HCI, or FCB; and GB ſhall be the Tangent of the Angle of Refraction GCB; and therefore, by meaſuring accurately upon a Scale the Lines FB and GB, you ſhall have the Proportion theſe Tangents bear to one another. From which, by the Rules of Trigonometry, the Angles themſelves, and their Sines, may eaſily be found.

If it be required to find the Refraction of Light coming out of Air into Water, or any other Fluid, the ſame may eaſily be found, by ſubſtituting, in place of the ſolid cubical Glaſs, a thin glaſs Veſſel of the ſame Figure and Magnitude filled with Water, or any other Fluid whoſe Refraction is ſought.

There are many other Methods whereby the Powers of Bodies in refracting of Light are found: But, as the greateſt Part of them preſuppoſe a Knowledge of Dioptrics, I have made choiſe of the above Method from the learned KEPLER, as moſt eaſy and ſimple; leaving thoſe that are acquainted with Dioptrics to conſult the optical Writers for other Methods.

§ 13. Having propoſed a Method whereby the refractive Power of Bodies may be found, it now remains that we give you the Laws of Refraction, which are ſo many Corolaries drawn from the above Experiments, and confirmed by all other Methods.

COROL. 1. The Angles of Incidence and Refraction ly in one and the ſame Plane; that is, in the Plane drawn thro' the incident Ray and the Perpendicular at the Point of Incidence.

COROL. 2. Refraction out of a rarer *Medium* into a denſer, as out of Air into Water or Glaſs, is made towards the Perpendicular, that is, ſo that the Angle of Refraction be leſs than the Angle of Incidence; and, on the contrary, Refraction out of a denſer *Medium* into a rarer, as out of Glaſs into Air or Water, is made from the Perpendicular, ſo that the Angle of Refraction be greater than the Angle of Incidence.

COROL. 3. If the refracted Ray be returned directly back to the Point of Incidence, it ſhall be refracted into the Line before deſcribed by the Incident Ray.

COROL. 4. With whatever Obliquity the Light falls upon any refracting Surface, the Sine of the Angle of Incidence is always in a given Proportion to the Sine of the Angle of Refraction: Whence, if that Proportion be known in any one Inclination of the incident Ray, it is known in all Inclinations; and thereby the Refraction in all Caſes of Incidence, on the ſame refracting Body, may be determined.

SNELLIUS was the firſt who found that there was a conſtant *Ratio* of Refraction; which he proved by manifold Experiments. But he uſed the Secants of the Complements, inſtead of the Sines, for expreſſing that *Ratio*, and did not advert that thoſe Lines were to one another in the ſame Proportion as the Sines; and therefore did not fully comprehend the Uſefulneſs of his own Diſcovery.

What he diſcovered on this Head, is as follows: Suppoſing the Surface of Water to be

AB (ſee *Fig.* 12. PLATE II.) and an Object under it at D, which to the Eye at F appeared as it were in the Line FC; he produced this FC till it met in G, with the Perpendicular DA, to the Surface AB. Then he affirmed that the Image of the Object D appeared at G, and that CD was to CG in a certain given *Ratio*, as 4 to 3, if the Fluid was Water.

All this is very true, and agrees perfectly with the Law of Refraction now before us: for, from the known Properties of the Triangle CDG, the Side CD is to CG, as the Sine of the Angle DGC, or AGC, or HCF, to the Sine of CDG, or DCE, which are the Angles of Incidence and Refraction; yet SNELLIUS never imagined that this was the *Ratio* of Sines; and therefore, as has been already ſaid, he did not thoroughly comprehend his own Invention.

DES CARTES, making uſe of this Invention of SNELLIUS, firſt applied the Sines, and therefore introduced no ſmall Light and Convenience to this Doctrine, and thence explained the Manner of Viſion and the *Foci* of Glaſſes more accurately than had formerly been done: For all optical Writers before him and SNELLIUS, ſuch as ALHAZEN, VITELLIO, KEPLER, *&c.* ſought for the Laws of Refraction in the *Ratio* of the Angles of Incidence to the Angles of Refraction; and therefore

fore could never come accurately to the Truth, eſpecially in large Angles, where the Error is moſt remarkable. But the Honour of this Diſcovery is by no means to be given to DES CARTES; tho' by many he has been reckoned the firſt Author of this Law; for, as is to be ſeen in HUGENIUS's *Dioptrics*, he certainly ſaw the Manuſcript of SNELLIUS, from whom he had this Diſcovery, tho' he is not ſo candid as to mention his Name.

COROL. 5. All Bodies ſeem to have their refractive Powers proportional to their Denſities, excepting ſo far as they partake more or leſs of ſulphureous oily Particles, and thereby have their refractive Power made more or leſs.

This is evident from the Experiments and Obſervations of the incomparable NEWTON, who, in his admirable Treatiſe of *Optics* (*Book* II. *part* 3. *Prop.* 10.) has given us an exact Table wherein the Proportion of the Sines of Incidence and Refraction of almoſt all tranſparent Bodies, the proportional refracting Force of theſe Bodies, (eſtimated on the Suppoſition that Light is ſwifter in Bodies than *in vacuo*, in the Proportion of the Sines which meaſure the Refraction of Bodies; which is certainly true, as ſhall be demonſtrated afterwards.) The Denſity of the Bodies eſtimated by their ſpecific Gravity, and the refractive Power of each Body in reſpect of its Denſity, are ſet down in different Columns. From which it appears, that the Refractions of a *Pſeudo-topaz*, a *Selenitis*, Rock Cryſtal, *Iſland* Cryſtal, vulgar Glaſs, and Glaſs of Antimony, which are terreſtrial ſtony alcalizate Concretes, and Air, which probably ariſes from ſuch Subſtances by Fermentation, tho' theſe be Subſtances very different from one another in Denſity, yet they have their refractive Powers almoſt in the ſame Proportion to one another as their Denſities are.

Again, the Refraction of Camphire, Oil-olive, Lintſeed-oil, Spirit of Turpentine and Amber, which are fat, ſulphureous, unctuous Bodies, and a Diamond, which probably is an unctuous Subſtance coagulated, have their refractive Powers in Proportion to one another as their Denſities, without any conſiderable Variation. But the refractive Power of theſe unctuous Subſtances, is two or three times greater in reſpect of their Denſities than the refractive Powers of the former Snbſtances in reſpect of theirs.

Water has a refractive Power in a middle Degree between thoſe two Sorts of Subſtances, and probably is of a middle Nature; for out of it grow all vegetable and animal Subſtances, which conſiſt, as well of ſulphureous, fat and inflammable Parts, as of earthy, lean and alcalizate ones.

Salts and Vitriols have refractive Powers in a middle Degree between thoſe of earthy Subſtances and Water, and accordingly are compoſed of thoſe two Sorts of Subſtances: For, by Diſtillation and Rectification of their Spirits, a great Part of them goes into Water, and a great Part remains behind in the Form of a dry, fixed Earth, capable of Vitrification.

Spirit of Wine has a refractive Power in a middle Degree between thoſe of Water and oily Subſtances, and accordingly ſeems to be compoſed of both, united by Fermentation; the Water, by means of ſome ſaline Spirits, with which it is impregnated, diſſolving the Oil, and volatilizing it by the Action; for Spirit of Wine is inflammable by means of its oily Parts, and, being diſtilled often from Salt of Tartar, grows, by every Diſtillation, more and more aqueous and phlegmatic; and Chymiſts obſerve, that Vegetables, as Lavender, Rue, Marjoram, *&c.* diſtilled *per ſe*, before Fermentation, yield Oils without any burning Spirits; but, after Fermentation, yield ardent Spirits, without Oils: Which ſhews, that their Oil is, by Fermentation, converted into Spirit. They find alſo, that, if Oils be poured in ſmall Quantity upon fermenting Vegetables, they diſtil over, after Fermentation, in the Form of Spirits.

So then it appears, by the forementioned Table, that all Bodies have their refractive

Powers proportional to their Denſities, or very nearly, excepting ſo far as they partake more or leſs of ſulphureous, oily Particles, and thereby have their refractive Power made greater or leſs. Whence it ſeems rational to attribute the refractive Power of all Bodies chiefly, if not wholly, to the ſulphureous Parts with which they abound; for it is probable, that all Bodies abound, more or leſs, with Sulphurs; and, as Light, congregated by a burning Glaſs, acts moſt upon ſulphureous Bodies, to turn them into Fire and Flame; ſo, ſince all Action is mutual, Sulphurs ought to act moſt upon Light: For, that the Action between Light and Bodies is mutual, may appear from this Conſideration, that the denſeſt Bodies which refract and reflect Light moſt ſtrongly, grow hotteſt in the Summer Sun, by the Action of the refracted and reflected Light.

§ 14. To this general Law of Light's being refracted more or leſs as the *Mediums* are of different Denſities, and as they partake more or leſs of ſulphureous, oily, and inflammable Parts, I ſhall now add, in particular, the Proportion between the Sines of Incidence and of Refraction, in Glaſs, Water, and the Humours of the Eye. Theſe will be ſufficient for our preſent Purpoſe; and thoſe who deſire to know what this Proportion is in other Bodies, may conſult HAUKSBEE's Experiments, NEWTON's *Optics*, *&c.*

Light, in paſſing out of Air into Glaſs, is refracted towards the Perpendicular, ſo as the Sine of the Angle of Incidence, is to the Sine of the Angle of Refraction in a greater Proportion than that of 114 to 76, but leſs than 115 to 76, that is, nearly as 3 is to 2; as HUGENIUS has obſerved: With which alſo NEWTON's Obſervations do nearly agree; for he makes the Proportion to be as 31 is to 20, which differs not much from that of 3 to 2; and therefore this Proportion of 3 to 2 is commonly uſed by dioptrical Writers in explaining the Refractions and *Foci* of Glaſs *Lenſes*, tho', at the ſame time, different Glaſſes are ſometimes of different Denſities, and conſequently do not refract Light equally. But in Phyſical Matters there is ſeldom need of greater Accuracy.

In going out of Air into Rain-water, DES CARTES has obſerved, that the Sine of Incidence is to that of Refraction, as 250 is to 187, that is, nearly as 4 to 3. This alſo agrees with NEWTON's Obſervation, who makes the Sine of Incidence to that of Refraction as 529 to 396.

As to the refractive Powers of the aqueous and vitreous Humours, ſeeing I have already ſhewn that they agree with Water in their ſpecific Gravities, and conſequently in their Denſities; and ſeeing it is probable that they are all equally ſulphureous or oily, it may reaſonably be perſumed, that they alſo agree with Water in their Refractions; and therefore the Sine of Incidence, out of Air into theſe Humours, muſt be to the Sine of Refraction, as 4 to 3. It is not eaſy to collect ſuch a Quantity of the aqueous Humour as to prove this experimentally: But Mr. HAUKSBEE, in his *Phyſico-Mechanical Experiments*, has done it with regard to the vitreous Humour of an Ox's Eye; and found that it refracted Light the ſame as Water, namely, in the *Ratio* of 10000 to 7485.3, which is nearly the ſame with that of 4 to 3.

In paſſing out of Air into the Cryſtalline of an Ox's Eye the ſame Mr. HAUKSBEE found the Sines of Incidence and Refraction to be to one another in the Proportion of 10000 to 6832.7, which is nearly as 19 to 13. And this being ſo, the Proportion between theſe Sines, in paſſing out of the aqueous Humour into the Cryſtalline, will be as 11 to 10.02126, and in paſſing out of the cryſtalline into the vitreous Humour, as 10.02126 to 11.

For the Refraction out of Air into the Cryſtalline being, according to Mr. HAUKSBEE's Experiment, as 10000 to 6832.7; and this Refraction being compounded of the Refraction out of Air into the aqueous Humour, and the Refraction out of the aqueous Humour into the Cryſtalline, if, for the Sine of Incidence, from the aqueous Humour into the Cryſtalline, you put 3, and for the Sine of Refraction R, we ſhall have the following Analogy; $10000 : 6832.7 :: 4 : 3+ :: 3 : R$, that is $10000 : 6832.7 :: 12 : 3R$, or as 4 to R. Whence $10000\,R = 27330.8$, and $R = \frac{27330.8}{10000} = 2.73308$; but the Sine of Incidence was 3; therefore the Sine of Incidence will be to the Sine of the Refraction, as 3 to 2.73308, that is as 11 to 10.02129, when the Light paſſes from the aqueous Humour into the Cryſtalline, and as 10.02129 to 11, when it paſſes from the Cryſtalline into the vitreous Humour.

This is the Law of Refraction in the Cryſtalline of an Ox; and this alſo it would be in the human Cryſtalline, were the human Cryſtalline of equal Denſity with that of an Ox. But there is good Reaſon to believe, that it is not ſo denſe, and conſequently that its refracting Power is weaker; for, as has been before obſerved, Dr. ROBERTSON has informed us, that, upon weighing the Humours of the Eye in a hydroſtatical Balance, he found that the mean ſpecific Gravities of five cryſtalline Humours of Oxen's Eyes, and three cryſtalline

line Humours of Sheep's Eyes, were 11134 and 11033, the ſpecific Gravity of Water being 10000; and as the Cryſtallines of Oxen differ ſo much in their ſpecific Weight from the Cryſtallines of Sheep, it is not improbable that they differ alſo from the human Cryſtalline; and that they do really differ, ſeems evident from what has been before obſerved from Dr. PETIT, *viz.* That the Cryſtalline of an Ox falls immediately to the Bottom of Spirit of Vitriol; whereas the human Cryſtalline floats in it, and does not deſcend till next Day, that its ſpecific Weight has been ſufficiently increaſed by the Action of the acid Spirit.

§ 15. It ſeems therefore to be without Foundation, that a great many learned Men, both Phyſicians and Philoſophers, have ſuppoſed that the human Cryſtalline obſerves the ſame Law in the Refraction of Light with the Cryſtalline of Oxen, and have accordingly built ſome of their niceſt Calculations on that Suppoſition: And as no Author I have met with has examined the Refraction of the human Cryſtalline experimentally, and as ſuch Experiments may poſſibly be attended with ſome Difficulties, I ſhall here ſhew how the Refraction of this Humour may be accurately determined from its ſpecific Weight alone, which may be more eaſily found. But, in order to this, I muſt premiſe the following *Lemma* and *Axioms*:

LEM-

LEMMA.

§ 16. *The perpendicular Motion of Light, which is generated in Refraction by the attractive Force of the refracting Body, is always in a ſubduplicate Proportion of that Force; or, which is the ſame thing, the refracting Force of the Body is as the Square of the perpendicular Motion generated in Refraction.*

Illusration. Let AB (*Fig* 13. Plate II.) repreſent the refracting plain Surface of any Body, and IC a Ray incident very obliquely upon the Body at C, ſo that the Angle ACI may be infinitely little; and let CR be the refracted Ray: From a given Point B, perpendicular to the refracting Surface, erect BR, meeting with the refracted Ray CR, in R; and if CR repreſent the Motion of the refracted Ray, and this Motion be diſtinguiſhed into the Motions CB and BR, whereof CB is parallel to the refracting Surface, and BR perpendicular to it, CB ſhall repreſent the Motion of the incident Ray, and BR the perpendicular Motion generated in Refraction by the attractive Power of the Body; as Opticians have explained. I ſay then, that this Motion BR is in a ſubduplicate Proportion to the refracting Force of the Body; that is, the refracting Force of the Body is as BR^2.

DEMONSTRATION. BR is an uniform Velocity already compleatly produced by the refracting Force; but this Force does not act inſtantaneouſly, but is gradually exerted upon the Ray during its whole Paſſage thro' the Space of Activity of the refracting Body: Wherefore, let B and *b* be two Bodies of different refracting Forces, and let theſe Forces be F and *f*, and let the perpendicular Motion generated by theſe Forces be M and *m*, and the Times in which they are generated, or the Times the Rays take to paſs thro' the whole Space of Attraction, T and *t*; it is obvious, that the Velocities produced will be in a compound *Ratio* of the Forces and Times; that is, $M : m :: F \times T : f \times t$. But the Times are reciprocally as the Velocities; therefore $M : m :: Fm : fM$; whence $F \times m^2 = f \times M^2$; which gives this Analogy, $F : f :: M^2 : m^2$ or $\sqrt{F} : \sqrt{f} :: M : m$, that is, the perpendicular Motion generated in the Refraction by the attractive Force of the Body is always in a ſubduplicate Proportion of that Force, or, which is the ſame thing, the refracting Force of the Body is as the Square of the perpendicular Motion generated in Refraction.

AXIOM. I. *Putting* I *for the Sine of Incidence, and* R *for the Sine of Refraction, and* M *for*

for the perpendicular Motion generated by Refraction, M *ſhall be equal to* $\sqrt{I^2 - R^2}$; *and* M^2, *or the refracting Force of the Body, ſhall be equal to* $I^2 - R^2$. This will be demonſtrated afterwards. (See COROL. towards the End of the 26th Sect. of this Chap.)

AXIOM. II. *All Bodies,* cæteris paribus, *have their refracting Forces proportional to their Denſities.* This has already been demonſtrated from Experiments, and ſhall alſo be demonſtrated afterwards *a priori.* (See Sect. 26. of this Chap. towards the End.)

If what has been laid down in the preceeding *Lemma* and *Axioms* ſhall be admitted, it will not be difficult to ſhew, how, from the given Denſity of any Body, its Law of Refraction may be determined, by comparing the Body with ſome other ſimilar Body, ſuch, as Water, whoſe Denſity and Refraction are both given.

Thus, if the Refraction of the human Cryſtalline be ſought; if, for its given Denſity, you put D, and for its unknown refracting Force M^2, and for the given Denſity of Water d, and for its given refracting Force m^2; by ſecond *Axiom,* d is to m^2, as D is to M^2; whence $M^2 = \frac{Dm^2}{d}$. But, By *Ax.* I. $M^2 = I^2 - R^2$, and therefore $I^2 - R^2 = \frac{Dm^2}{d}$; and if, for the Sine of Refraction R, we put Unity, we ſhall have $I^2 - 1 = \frac{Dm^2}{d}$; whence $I^2 = \frac{Dm^2}{d} + 1$, and $I = \sqrt{\frac{Dm^2}{d} + 1}$. But I is the Sine of Incidence from Air into the human Cryſtalline, and 1 the Sine of Refraction; wherefore the Sine of Incidence ſhall be to the Sine of Refraction, as the known Quantity $\sqrt{\frac{Dm^2}{d} + 1}$, to 1.

Nota, As in ſolving this Problem we made the Sine of Refraction out of Air into the Cryſtalline equal to Unity; ſo, in reducing $\sqrt{\frac{D \times m^2}{d} + 1}$. to Numbers, the Sine of Refraction from Air into Water muſt in like manner be ſuppoſed equal to Unity; whence the Sine of Incidence will be $\frac{4}{3}$, and m^2 or $I^2 - R^2$ will be $\frac{7}{9}$; which I thought proper to notice, to prevent Miſtakes.

SCHOLIUM I. It has been noticed above, that Dr. ROBERTSON, upon weighing the Humours of the Eye in a hydroſtatical Ballance, found, that the mean ſpecific Gravities of 5 cryſtalline Humours of Oxen's Eyes, and of three cryſtalline Humours of Sheep's Eyes, were 11134 and 11033, the ſpecific Gravity of Water being 10000; and the Mean of theſe Means being 11083; if from this, it ſhall be ſuppoſed, that the Denſity of the human Cryſtalline is to that of Water, as 11083 to 10000, then $\sqrt{\frac{D\times m^2}{d} + 1}$, will be equal to 1.3645; and therefore the Sine of Incidence from Air into the human Cryſtalline, will be to the Sine of Refraction, as 1.3645 to 1, or as 4.0936 to 3.

SCHOLIUM 2. This Refraction out of Air into the Cryſtalline being compoſed of the Refraction out of Air into the aqueous Humour, and the Refraction out of the aqueous Humour into the Cryſtalline; if, for the Sine of Incidence from the aqueous Humour into the Cryſtalline, you put 3, and for the Sine of Refraction R, we ſhall have 4.0936 to 3 in a compound Proportion of 4 to 3 and 3 to R, that is, as 12 to 3 R, or as 4 to R; whence $R = \frac{12}{4.0936}$. But the Sine of Incidence was 3, and therefore the Sine of Incidence is to the Sine of Refraction, as 3 to $\frac{12}{4.0936}$, that is, nearly as 87 to 85, when the Light paſſes out of the aqueous Humour into the Cryſtalline; and as 85 to 87, when it paſſes from the Cryſtalline into the vitreous Humour. This is a ſurpriſingly ſmall Refraction, and yet it is as certain as any Thing in EUCLID, that it can be no greater; and, were our Cryſtalline no denſer than that of Sheep, its Refraction would be ſtill leſs.

§ 17.

§ 17. It muſt here be obſerved, that what I have hitherto ſaid concerning the Meaſures of Refraction, is not accurately true of all the Rays of Light; for, as will appear afterwards, the Light is not all ſimilar and homogeneal, but compoſed of different and diſſimilar Rays, each of which are endowed with different Properties, ſome being more refrangible, and ſome leſs refrangible, *&c.* and therefore the above Proportions of the Sines of Incidence and Refraction, can only be accurately true of thoſe Rays which have a middle Degree of Refrangibility, ſuch as the Green-making Rays. But the Difference betwixt the Refractions of theſe and the other Rays is ſo very ſmall, that it is not much to be obſerved, excepting in great Refractions, when the Incidence is very oblique; and therefore, in moſt Caſes, it may be intirely neglected, without any ſenſible Error.

§ 18. As to what concerns the Cauſe of this Reflection and Refraction of Light, ſeeing our great Philoſopher, the famous Sir ISAAC NEWTON, has clearly demonſtrated, by unexceptionable Experiments, that Bodies act upon the Rays of Light at a Diſtance, in refracting, reflecting and inflecting them, and that the Rays mutually agitate the Parts of Bodies at a Diſtance, for heating them, and putting their Parts into a vibrating Motion, wherein Heat conſiſts; we may ſafely conclude, that Bodies and Light attract and repel each other mutually; and that the Refraction and Reflection of Light proceeds from the Powers, Virtues or Forces, which Bodies have to attract and repel its Rays at a Diſtance: For from ſuch Powers, variouſly exerciſed in various Circumſtances, all the *Phænomena* of Reflection and Refraction may eaſily be deduced. And this being ſo, it is unphiloſophical to ſeek for any other Cauſe; for Nature does nothing in vain, and in vain that is done by more Cauſes, which can be done by fewer. She is therefore very ſimple and uniform, and delights not in ſuperfluous Cauſes of Things.

§ 19. This attractive and repulſive Power, by which Bodies and Light act upon one another at a Diſtance, is not miraculous or uncommon, but very conformable to the uſual Courſe and Tenor of Nature; for it is well known, that Bodies act one upon another by the Attractions of Gravity, Magnetiſm, and Electricity: Theſe Attractions reach to very ſenſible Diſtances, and ſo have been obſerved by vulgar Eyes; and there are others which reach to ſo ſmall Diſtances, as to have eſcaped every body's Obſervation, till NEWTON diſcovered them.

In the 31*ſt Query*, annexed to his *Optics*, this great Philoſopher has ſhown, in a moſt elegant and maſterly Manner, how all the chymical Operations are performed by ſuch attractive Powers. The Coheſion of the Parts of all homogeneal hard Bodies, is another inſtance of this Sort of Attraction; for explaining which Coheſion ſome have invented hooked Atoms; which is begging the Queſtion, ſeeing the Parts of thoſe Atoms do alſo cohere. Others tell us, that Bodies are glued together by reſt, that is, by an occult Quality, or rather by nothing; and others, that they ſtick together by conſpiring Motions, that is, by relative Reſt amongſt themſelves. But theſe Cauſes are altogether inſufficient for explaining Coheſion; and it is evident, that the Particles attract one another by ſome Force, which, in immediate contact, is exceeding ſtrong, at ſmall Diſtances, performs the chymical Operations, and reaches not far from the Particles with any ſenſible Effect; for it is impoſſible that the Parts or Particles which compoſe Bodies can ſtick together, and that ſo firmly as they do, without the Aſſiſtance of ſomething which cauſes them to be attracted or preſſed towards one another. And this is what I call *Attraction*, whatever that cauſe be. The Coheſion of two poliſhed Marbles *in Vacuo* is another Inſtance of this Sort of

Attraction; as is alſo the ſtanding of Quickſilver in the Barometer, at the height of 50, 60 or 70 Inches, or above, whenever it is well purged of Air, and carefully poured in, ſo that its Parts be every where contiguous, both to one another, and to the Glaſs. The Atmoſphere, by its Weight, preſſes, the Quickſilver into the Glaſs to the height of 29 or 30 Inches, and ſome other Agent raiſes it higher, not by preſſing it into the Glaſs, but by making its Parts ſtick to the Glaſs, and to one another; for, upon any Diſcontinuation of Parts made, either by Bubbles, or by ſhaking the Glaſs, the whole Mercury falls down to the Height of 29 or 30 Inches. And of the ſame Kind is that Attraction by which Liquors aſcend in capillary Tubes, and betwixt poliſhed Plates of Glaſs laid together, ſo as their Sides be at a very ſmall Diſtance from one another. And, by the ſame Principle, a Spunge ſucks in Water, and probably the Glands of the Bodies of Animals, according to their ſeveral Natures and Diſpoſitions, ſuck in various Juices from the Blood. The Hardneſs and Elaſticity of Bodies proceeds alſo from the ſame Cauſe; and the Drops of every Fluid affect a round Figure, by the mutual Attraction of their Parts; as the Globe of the Earth and Sea affects a round Figure by the mutual Attraction of its Parts by Gravity.

And, as the attractive Power by which Bodies and Light act mutually on each other at a Diſtance, is very conformable to the Courſe and Tenor of Nature; ſo alſo is their repulſive Power. For, ſince Metalls diſſolved in Acids attract but a ſmall Quantity of the Acid, their attractive Force can reach but to a ſmall Diſtance from them; and as in *Algebra*, where affirmative Quantities vaniſh and ceaſe, their negative Ones begin; ſo in Mechanics, where Attraction ceaſes, their a repulſive Virtue ought to ſucceed; and that there is ſuch a Virtue, follows from the Production of Air and Vapour: The Particles, when they are ſhaken off from Bodies by Heat or Fermentation, ſo ſoon as they are beyond the reach of the Attraction of the Body receding from it, and alſo from one another with great Strength, and keeping at a Diſtance, ſo as ſometimes to take up above a Million of Times more Space than they did before, in the Form of a denſe Body. Which vaſt Contraction and Expanſion ſeems unintelligible by feigning the Particles of Air to be ſpringy and ramous, or rolled up like Hoops, or by any other Means than a repulſive Power. The Particles of Fluids which do not cohere too ſtrongly, and are of ſuch a Smallneſs as renders them moſt ſuſceptible of theſe Agitations which keep Liquors in a Fluor, are moſt eaſily ſeparated and rarified into Vapour; and, in the Language of the Chymiſts, they are volatile, rarifying with an eaſy Heat and condenſing with Cold. But thoſe which are groſſer, and ſo leſs ſuſceptible of Agitation, or cohere by a ſtronger Attraction, are not ſeparated without a ſtronger Heat, or perhaps not without Fermentation; and theſe laſt are the Bodies which Chymiſts call fixed, and, being rarified by Fermentation, become true permanent Air: Thoſe Particles receding from one another with the greateſt Force, and being moſt difficultly brought together, which, upon Contact, cohere moſt ſtrongly. And, becauſe the Particles of permanent Air are groſſer, and ariſe from denſer Subſtances, than thoſe of Vapours; hence it is, that true Air is more ponderous than Vapour, and that a moiſt Atmoſphere is lighter than a dry one, Quantity for Quantity.

From the ſame repelling Power it is, that Flies walk upon the Water without wetting their Feet, and that the Object-glaſſes of long Teleſcopes lie upon one another without touching, and that dry Powders are difficultly made to touch one another ſo as to ſtick together, unleſs by melting them, or wetting them with Water, which, by exhaling, may bring them together, and that two poliſhed Marbles, which by immediate Contact ſtick together,

together are difficultly brought ſo cloſe together as to ſtick.

§ 20. Theſe Inſtances of Attraction and Repulſion ſhew the Courſe and Tenor of Nature, and make it highly probable, that there are yet others of the ſame or different Kinds governed by the ſame or different Laws; for Nature is very conformable to herſelf, and very ſimple and uniform: And that there are others, and particularly that Light is refracted, reflected, and inflected, by the attractive and repulſive Power of Bodies acting on the Rays at a Diſtance, clearly follows from NEWTON's Experiments and Obſervations: To him therefore I muſt refer the Reader for a full Proof of this Point, and ſhall here only, by way of Corolary, make the following Obſervation, *viz.*

§ 21. If Light is reflected and inflected by the repulſive Power of Bodies, it follows, that it may alſo be emitted from luminous ſhining Bodies by the ſame Cauſe; for, as the Particles of fixed denſe Bodies, when they are by Heat or Fermentation ſhaken off from theſe Bodies, ſo ſoon as they get beyond the Reach of the Attraction of the Body, recede from it and from one another with great Force, ſo as to conſtitute true Permanent elaſtic Air: So, in like manner, the Ray of Light, ſo ſoon as it is ſhaken off from a ſhining Body, by the vibrating Motion of the Parts of the

Body, and gets beyond the Reach of its Attraction, muſt be driven away with exceeding great Velocity by the repelling Force of the ſhining Body; for the repelling Force, which is ſufficient to turn it back in Reflection, muſt be ſufficient to emit it.

§ 22. It now remains, that I ſhow, how from this attractive and repulſive Power, all the *Phænomena* of Reflection and Refraction may be deduced.

For this End let ABCD (*Fig.* 14. PLATE II.) be a denſe pellucide Body, and let its Power to attract Light without the Body extend to KL; and let MN and KL be parallel, and at equal Diſtance from AB; it is obvious, that the attractive Force muſt continue within the Body till the Ray gets to MN; by reaſon that in all the Places betwixt the Surface of the Body AB and MN, there are more Particles drawing the Ray forwards towards MN, than drawing it backwards the contrary Way towards AB; and therefore the Ray, in its whole Paſſage fron KL to MN, muſt have its perpendicular Velocity continually accelerated, by the Power of Attraction acting conſtantly in Lines perpendicular to the Surface of the attracting Body: The Extent of this Power will therefore be terminated by the two Planes KL and MN, parallel to one another, and to the Surface of the Body AB:

Where this attractive Power vaniſhes at KL, there let a repulſive Power begin, and let this repulſive Power extend to the Diſtance IH, it is obvious, that the Ray, in its whole Paſſage from HI to KL, muſt have its perpendicular Velocity more and more retarded by the repulſive Power of the Body acting inceſſantly in Lines perpendicular to its Surface AB, and that the Extent of this Power will be terminated by the two Planes HI and KL, parallel to one another and to the Surface AB.

§ 23. This being premiſed, it will be eaſy to underſtand how theſe Powers operate in cauſing Reflections and Refractions.

Thus, if a Ray of Light OP falls obliquely from Air or *Vacuum*, upon the Space of Repulſion HIKL, this Ray, at its Incidence at P, will have its perpendicular Motion retarded, and conſequently will be perpetually diverted from one Direction into another, by the Oppoſition of the repulſive Force, and ſo will deſcribe a Curve PQR, till it emerges from that Space at R, and then it will proceed in the right Line RS. This will be the Courſe of the Ray, if its progreſſive Force be ſo weak, or its Incidence ſo oblique, or the repulſive Force ſo ſtrong, as to hinder it from entering the Space of Attraction KLMN; for, if it enters this Space, inſtead of being reflected, it will be refracted into the denſe *Medium*; and, in reality, ſome Part of the incident Light is always reflected and ſome refracted at all tranſparent Surfaces: The Cauſe of which is, that ſome of the Rays are in Fits of eaſy Reflection, while others are in Fits of eaſy Tranſmiſſion; as NEWTON has explained (*Optics p.* 253.)

If *op* be another Ray, having its perpendicular Velocity greater than that of the Ray OP, by being leſs oblique to the Surface of the Body AB, or by being in a Fit of eaſy Tranſmiſſion at its Incidence; this Ray, at its Incidence upon the repelling Space at *p*, will alſo have its perpendicular Motion retarded, and conſequently will be perpetually diverted from one Direction into another by the Oppoſition of the repulſive Force, and ſo will deſcribe the Curve *pq*: But, as the repulſive Force is here ſuppoſed not ſo ſtrong as to deſtroy the perpendicular Velocity of the Ray before it gets to the Space of Attraction at *q*, this attractive Power which begins at *q*, muſt again accelerate the perpendicular Velocity of the Ray; and of conſequence muſt bend its Courſe into the Curve *qr*; and when the Ray has got thro' the Space of Attraction to *r*, it will then proceed in the right Line *rs* with an uniform Velocity.

This is the Manner in which the repulſive and attractive Powers of denſe *Mediums* operate,

rate, in cauſing Reflections and Refractions, when the Light moves from a rare *Medium*, or a *Vacuum*, into the denſe *Medium*; but there is a ſecond Reflection and Refraction at the farther Surface of the denſe *Medium* when the Light emerges from the denſe *Medium* into the rare *Medium* or a *Vacuum*.

For Underſtanding this, let a Ray of Light be ſuppoſed to move the contrary Way from *s* to *r*; this Ray, during its whole Paſſage thro' the Space of Attraction MNKL, being conſtantly drawn back by the attractive Power of the *Medium* acting obliquely upon the Particles, will bend their Courſe into the Curve *rq*: But, if the attractive Force is not ſo ſtrong as to deſtroy the perpendicular Velocity of the Ray, before it gets to the Space of Repulſion at *q*, this repulſive Power, which begins at *q*, muſt again accelerate the perpendicular Velocity of the Ray, and of conſequence muſt bend its Courſe into the Curve *qp*; and when the Ray has got thro' the Space of Repulſion to *p*, it will then proceed in the right Line *po*.

This will be the Courſe of the Ray, if its progreſſive Force be ſo ſtrong as to overcome the attractive Force of the Body, and get into the Space of Repulſion; but, if the incident Ray have its perpendicular Velocity ſo much diminiſhed, either by its being in a Fit of eaſy ſy Reflection, or by its Obliquity to the Surface of the Body, as not to be able to paſs thro' the ſpace of Attraction, it will be pulled back into the ſame *Medium*, and, in place of being refracted, it will be reflected.

Thus the Ray *op* (*Fig.* 15.) falling more obliquely upon the Space of Attraction at *p*, will, by the Force of Attraction acting ſideways upon its oblique Courſe, be perpetually drawn out of one Direction into another, and be made to deſcribe a Curve *pqr*, till it emerges from the Space of Attraction at *r*, and then it will proceed in the right Line *rs*. This may be illuſtrated by the Action of Gravity; for, if a Stone be thrown upwards from the Point *p*, in the Direction of the Line *op* continued, its Courſe will be bent by its Gravity into a Curve *pqr*, and the Stone will deſcend from the higheſt Point of its Courſe *q*, by the ſame Degrees of Curvity with which it aſcended; and if its Gravity be ſuppoſed to ceaſe in all Places below the Line MN, the Stone will go on in the Direction of the laſt Particle of the Curve produced, that is, in the right Line *rs*.

§ 24. From what has been ſaid of the repulſive and attractive Power of Bodies, it follows as a Corollary, that the repulſive Power of a denſe *Medium* is leſs extended, or elſe weaker than the attractive Power; For if the bending of a Ray, by the repulſive Power, was not leſs than the contrary bending made by the attractive Power, the Refraction into a denſe *Medium* could not be made toward the Perpendicular, and the Refraction into a rare *Medium* from the Perpendicular, as it always is. And that the repulſive Power of a denſe *Medium* is leſs extended than the attractive Power, ſeems manifeſt, becauſe the attractive Power continues after the Ray enters the denſe Body: Thus, (in *Fig.* 14.) the Extent of the repulſive Power is terminated by the two Planes HI and KL; whereas the attractive Power extends not only from the Plane KL, to the Surface of the Body AB, but alſo from this Surface AB to the Plane MN; which is double the Extent of the repulſive Power: And it is from this greater Extent of the attractive Power that the Refraction of Bodies is to be explained.

§ 25. Having thus explained the Manner in which the Powers of Repulſion and Atttraction operate in cauſing Reflections and Refractions, I ſhall now proceed to ſhew, more particularly, how, from theſe Powers all the *Phænomena* of Reflection and Refraction may be deduced: But, becauſe theſe Powers are but of a ſmall Extent, and vaniſh at a very ſmall Diſtance from the Body, the Curve deſcribed by the Rays, in Reflections and Refractions, muſt be very ſhort; and therefore, for the more eaſy Conception of what is to follow, we may ſuppoſe that the Ray moves in a right Line quite to the Surface of the reflecting or refracting Body, and that it is reflected and refracted, not in a Curve, but all at once at the Point of Incidence on that Surface.

Taking it then for granted, that Light is reflected from opaque Bodies, and from the firſt Surface of tranſparent Bodies, by this repelling Power acting upon the Rays in Lines perpendicular to the Surface of the denſe reflecting Body, it will thence follow, that the Angle of Incidence is equal to the Angle of Reflection.

For, if we ſuppoſe a Ray of Light to move in the Direction AC (Plate II. *Fig.* 16.) towards the reflecting Surface BCD; and if we ſuppoſe that Motion to be reſolved into two, one AE, parallel to BD, and the other AB, perpendicular to BD, it is manifeſt, that of theſe two Motions, the latter only is oppoſed to the repelling Force, and of conſequence, the Ray, after Reflection, will go on in the parallel Direction with the ſame Velocity it did before; and foraſmuch as the repelling Force, which oppoſes the perpendicular Motion, acts inceſſantly, it muſt, after having deſtroyed the Motion of the Ray towards the Body, give it an equal Degree of Motion the contrary Way; that is, throw it back with the ſame perpendicular Velocity wherewith it approached. If therefore CD be taken equal to AE, and from C be raiſed the Perpendicular CE, equal and parallel to AB; CD will expreſs the parallel Motion of the Ray after Reflection, and CE, its perpendicular Motion: And, having compleated the Paralellogram ED, which will in every reſpect be equal and ſimilar to the Paralellogram BE, and drawn the Diagonal CG, this Diagonal CG will be actually deſcribed by the Ray, by virtue of its compound Motion; and, from the Nature of ſimilar Triangles, the Angle of Incidence ACE will be equal to ECG, the Angle of Reflection.

In like manner, taking it for granted that Light is reflected at the further Surface of tranſparent denſe Bodies, by the attractive Power of the Body acting upon the Rays in Lines perpendicular to its Surface, and drawing them back from the rare *Medium* or *Vacuum* which lies behind that Surface; in this Caſe alſo the Angle of Incidence will be equal to the Angle of Reflection.

This ſcarce needs any Demonſtration: For, if we ſuppoſe ABDG to be a denſe tranſparent Body (See ſtill *Fig.* 16.) and AC a Ray of Light moving towards the further Surface of the Body BCD; it is obvious, that the Effect muſt be the ſame, whether the Ray be puſhed back by a repelling Force, before it has got to the Surface BCD; or whether it be pulled back in the ſame perpendicular Direction by an attracting Force, after it has paſſed that Surface. In both Caſes, the Ray will have its perpendicular Motion deſtroyed; after which, by the continued Action of theſe Powers, it will get an equal Degree of Motion the contrary way; that is, it will be ſent back with the ſame perpendicular Velocity wherewith it went forward. But it has been already ſhown, that this perpendicular retrograde Motion being compounded with the parallel Motion of the Ray, carries the Ray into ſuch a Direction as makes the Angle of Incidence equal to the Angle of Reflection; whence we conclude, that, if Light is reflected by the attractive and repulſive Power of Bodies, whether this Reflection be made at the firſt or ſecond Surface of the Body, the Angle of Incidence will always be equal to the Angle of Reflection, with whatever Obliquity the Ray falls on the reflecting Surface. And this is a fundamental leading Principle whereon a great Part of the Doctrine of Catoptrics is founded.

§ 26. As to the *Phænomena* of Refraction; theſe alſo may be eaſily deduced from the attractive Power of the denſer *Medium* acting upon the Rays at Right-angles to the Surface.

For Proof of this, let AC (PLATE II. *Fig.* 17.) be a Ray of Light moving from A to C, and there entring into a denſer *Medium*, the Surface which ſeparates the two *Mediums* being denoted by the Line HK; the Motion of the Ray, in the Direction AC being reſolved, according to the known Method, into two, one in the Direction AD, and the other in the Direction AB or DC, whereof the former is parallel, and the latter perpendicular to HK; it is manifeſt, that, as the Ray enters into the denſer *Medium* at C, its perpendicular Motion muſt be accelerated by the Attraction of the *Medium*, whilſt its parallel Motion continues the ſame. Let then the Line CG, be taken in the ſame Proportion to CD, that the Velocity of the perpendicular Motion after Refraction has to the Velocity thereof before the Refraction; and for as much as the parallel Motion is the ſame before and after Refraction, let CE be taken equal to AD or BC, and having compleated the parallelogram EG, and drawn the Diagonal CF, the Ray, after Refraction, will diſcribe the Line CF in the ſame time that it moved from A to C before the Refraction; and foraſmuch as GF is equal to AD, LM, that is the Sine of the Angle of Refraction MCL, muſt be leſs than AD the Sine of the Angle of Incidence ACD; conſequently, by the Attraction of the denſer *Medium*, the Ray, in paſſing into that *Medium*, is brought nearer to the Perpendicular; which is one of the *Phænomena* of Refraction.

Again, let FC denote the Motion of a Ray in the denſer *Medium* from F to C; and let this

Motion be reſolved into two others, one in the Direction FG, or EC, and the other in the Direction FE or GC, the former being Parallel and the latter perpendicular to HK: When the Ray paſſes into the rarer *Medium* at C, the parallel Motion does not ſuffer any Change from the Attraction, but the perpendicular Motion is retarded by the attractive Force, which in this Caſe, acts in direct Oppoſition to it: Let then CD be to GC as the perpendicular Velocity of the Ray in the rarer *Medium* to the perpendicular Velocity thereof in the denſer, and let DA be drawn equal and parallel to FG, in order to denote the parallel Motion of the Ray after Refraction; and the Diagonal CA will be the Line deſcribed by the Ray after Refraction, in a Space of Time equal to that wherein it deſcribed the Line FC before Refraction; and foraſmuch as AD is equal to GF, it muſt be greater then LM; conſequently the Angle ACD is greater than FCG; and therefore the Ray, in paſſing out of a denſer *Medium* into a rarer, is, by the Attraction of the denſer *Medium*, bent from the Perpendicular; which is another of the *Phænomena* of Refraction.

A *third Phænomenon* of Refraction is, that with whatever Obliquity the Light falls upon any refracting Surface, the Sine of the Angle of Incidence is always in a given Proportion to the Sine of the Angle of Refraction.

This alſo will follow from the attractive Force of the denſer *Medium*: For proving which, I muſt premiſe the following *Lemma:*

LEMMA.

If CD (Plate III. *Fig.* 18.) *be the Surface of the denſer* Medium *CDEF, and AB the Space thro' which the attractive Force extends itſelf from A to B; a Ray of Light, in paſſing from B to A, will be accelerated in ſuch a Manner as that the perpendicular Velocity thereof, at the Point A, will be equal to the Square-root of the Sum of the Square of the perpendicular Velocity of the Ray at its Incidence on the Point B, and of the Square of the perpendicular Velocity which it would have at A, ſuppoſing it began its Motion at B from a State of Reſt; and this holds true, not only when the attractive Force is ſuppoſed to act uniformly at all Diſtances, thro' the whole of the Space AB, but alſo when it acts differently at different Diſtances in any given Proportion.*

Demonstration. *Firſt,* Let it be ſuppoſed that the attractive Power acts uniformly at all Diſtances thro' the Space of Activity BA; in this Caſe, the Motion which it generates will, as to its Properties, correſpond with the Motion ariſing from Gravity; if therefore the Triangle EGH (Plate III. *Fig.* 19.) be taken to denote the Space BA, GH will expreſs the Velocity of a Ray at A, on Suppoſition that from a State of Reſt it begins its Motion at B; but, if at B it has a Velocity expreſſed by any right Line as IK, parallel to GH, let the Triangle be continued on till the Portion IFLK becomes equal to EGH; and FL will expreſs the Velocity of the Ray at the Point A; and foraſmuch as the Triangles EGH, EIK, and EFL, are ſimilar, their Areas are to one another as the Squares of the homologous Sides GH, IK, FL; and ſeeing the Triangle EFL is equal to the Sum of the two Triangles EGH and EIK (by Reaſon of the equal Areas EGH and IKLF,) therefore alſo the Square of FL will be equal to the Sum of the Squares of GH and IK; whence FL will be equal to the Square-root of the Sum of the Squares of GH and IK; that is, the perpendicular Velocity of the Ray at A (*Fig.* 18.) is equal to the Square-root of the Sum of the Square of the perpendicular Velocity of the Ray at its Incidence on the Point B, and of the Square of the perpendicular Velocity which it would have at A, on ſuppoſition that it began its Motion at B from a State of Reſt. But,

2dly, If the attractive Power acts with different Forces at different Diſtances, let the Space of Attraction AB [*Fig.* 20.] be divided into innumerable little Spaces B*e*, *ei*, *io*, *ou*, *uy*, *y*A, by the parallel plane Surfaces *e*, *i*, *o*, *u*, *y*; the Force of Attraction in each of theſe

Spaces being ſuppoſed equal, and in different Spaces unequal, the Velocities generated in theſe different Spaces will alſo be unequal; wherefore, let a repreſent the Velocity generated in the Space Be, b, the Velocity generated in the Space ei, c, the Velocity generated in the Space io, d, the Velocity generated in the Space ou, f, the Velocity generated in the Space uy, and g, the Velocity generated in the Space yA: It is obvious, that, if the Ray begins its Motion at B, from a State of Reſt, at e it will have the Velocity a, at i, the Velocity $\sqrt{a^2+b^2}$; at o, the Velocity $\sqrt{a^2+b^2+c^2}$; at u, the Velocity $\sqrt{a^2+b^2+c^2+d^2}$; at y, the Velocity $\sqrt{a^2+b^2+c^2+d^2+f^2}$, and at A, the Velocity $\sqrt{a^2+b^2+c^2+d^2+f^2+g^2}$; and if at B the Ray begins its Motion thro' the Space BA, with any given Velocity as x, it will at A have the Velocity $\sqrt{x^2+a^2+b^2+c^2+d^2+f^2+g^2}$; But x^2 is the Square of the perpendicular Velocity of the Ray at its Incidence on the Space of Attraction at B, and $a^2+b^2+c^2+d^2+f^2+g^2$, is the Square of the perpendicular Velocity it would have at A, on ſuppoſition that it began its Motion at B from a State of Reſt; and therefore the perpendicular Velocity of the Ray, at its emerging out of the Space of Attraction, ſhall be always

ways equal to the Square-root of the Sum of the Square of the perpendicular Velocity of the Ray at its Incidence on the Space of Attraction, and of the Square of the perpendicular Velocity which it would have at its Emergence from that Space, if at its Incidence on that Space its perpendicular Velocity was equal to nothing. And this holds true, as well when the attractive Power acts differently at different Diſtances, as when at all Diſtances it acts equally.

As a Corollary from this, it follows, that, if a Ray moves the contrary way from a denſe *Medium* into a rare one, the Ray will be retarded by the Oppoſition of the attractive Force, in ſuch a Manner as that the perpendicular Velocity thereof, at its emerging out of the Space of Attraction, ſhall be always equal to the Square-root of the Difference of the Square of the perpendicular Velocity of the Ray, at its Incidence on that Space, and the Square of the perpendicular Velocity that is deſtroyed by the attractive Force of the denſe *Medium* in paſſing thro' that Space.

As this *Lemma* and *Corollary* are fundamental Principles, that they may be the better remembered, I ſhall expreſs them in the ſhort Algebraical Manner. For which Purpoſe, Let the perpendicular Velocity of the Ray, at its Incidence on the Space of Attraction, be - - - - - - V

The perpendicular Velocity which is generated by the Power of Attraction, when the Ray moves towards the denſe *Medium*, and which is deſtroyed by the ſame Power when the Ray moves the contrary way towards the rare *Medium*, - - v

The Velocity of the Ray, in the denſe *Medium*, after it has paſſed thro' the Space of Attraction, - - - M

The Velocity of the Ray in the rare *Medium*, after it has paſſed thro' the Space of Attraction, - - - - - m

Then by the *Lemma* $M = \sqrt{V^2 + v^2}$

And by the Corollary $m = \sqrt{V^2 - v^2}$

This *Lemma* and Corollary being admitted, it will be eaſy to determine the Courſe and Velocity of the refracted Light, and to demonſtrate the *Phænomenon* of Refraction now before us, *viz. That the Sine of Incidence is always in a given Proportion to the Sine of Refraction.*

DEMONSTRATION. Let Mm (PLATE III. *Fig.* 21.) repreſent the refracting plane Surface of any denſe tranſparent Body, and let IC be the Courſe and Velocity of a Ray incident very obliquely upon the Body at C, ſo that the Angle MCI may be infinitely little; from C raiſe the Perpendicular CS, and continue it downwards to Q; and let C*p* be the perpendicular Velocity generated by the attractive Power of the Body: From the Centre C, with the *Radius* CM or CI, deſcribe the Circle MAS*m*Q; C*m* ſhall be the parallel motion of the Ray after Refraction, and C*p* its perpendicular Motion; having therefore compleated the Parallelogram *pm*, and drawn the diagonal CV, this Line CV ſhall repreſent the Courſe and Velocity of the Ray after Refraction.

In like Manner, let the *Radius* AC repreſent the Courſe and Velocity of any other incident Ray AC; this Motion AC being diſtinguiſhed into two Motions AD and AB or DC, one of which AD is parallel, and the other DC perpendicular to the refracting Surface; let C*x* be taken equal to C*p*, this Line C*x* will alſo denote the perpendicular Motion generated by the Attraction of the denſer *Medium*, and the Hypotheneuſe D*x*, being equal to $\sqrt{DC^2 + Cx^2}$, will meaſure the whole perpendicular Velocity of the Ray AC, in the denſer *Medium*. And foraſmuch as the Velocity of the parallel Motion is no way altered by the Attraction, if C*d* be taken equal to AD, and CP equal to D*x*, and the parallelogram P*d* be compleated, it is evident, that the Ray AC, after Refraction, will deſcribe the Diagonal C*v*, and the Velocity of its Motion will be meaſured by that Line.

From the Points N and E, to the Line CQ let fall the Perpendiculars NG and EF, theſe Lines NG and EF are the Sines of the Angles of Refraction VCQ and *v*CQ; and, by Reaſon of the ſimilar Triangles CGN and C*p*V, $NG : CG :: Vp$ or $MC : Cp$. Whence $Cp = \frac{MC \times CG}{NG}$; and by reaſon of the ſimilar Triangles CFE and CP*v*, $EF : CF :: vP$ or $AD : CP$; whence $CP = \frac{AD \times CF}{EF}$. If therefore, for C*p*, the perpendicular Velocity of the Ray CV, you write $\frac{MC \times CG}{NG}$, then, by the foregoing *Lemma*, CP, the perpendicular Velocity of any other Ray C*v*, will be $\sqrt{CD^2 + \frac{MC^2 \times CG}{NG^2}}$; but $CP = \frac{AD \times CF}{EF}$; therefore $\frac{AD \times CF}{EF} = \sqrt{CD^2 + \frac{MC^2 \times CG^2}{NG^2}}$: And, by ſquaring theſe equals, we have $\frac{AD^2 \times CF^2}{EF^2} = CD^2 + \frac{MC^2 \times CG^2}{NG^2}$; to which if the equals AD^2, and $MC^2 - CD^2$ be added, we ſhall have $AD^2 + \frac{AD^2 \times CF^2}{EF^2} = MC^2 + \frac{MC^2 \times CG^2}{NG^2}$

or $\frac{AD^2 \times EF^2 + AD^2 \times CF^2}{EF^2} = \frac{MC^2 \times NG^2 + MC^2 \times CG^2}{NG^2}$; and, if theſe Equals be divided by the Equals $EF^2 + CF^2$ and $NG^2 + CG^2$, they will give the Æquation $\frac{AD^2}{EF^2} = \frac{MC^2}{NG^2}$: Whence AD, the Sine of Incidence, is to EF the Sign of Refraction, as MC to NG, that is, in a given *Ratio*.

In this Demonſtration I have only conſidered the Light moving from a rarer *Medium* into a denſer one; but, by the ſame Way of reaſoning, the Propoſition may alſo be proved when the Light moves the contrary Way, from a denſer *Medium* into a rarer one. The Demonſtration Mathematicians will eaſily find out, and therefore I ſhall not trouble the Reader with it.

COROL. I. The perpendicular Motion generated in Refraction, by the Attraction of the Body, when the Ray moves from the rarer *Medium* into the denſer, is always equal to the Square-root of the Difference of the Square of the Sine of the Angle of Incidence, and of the Square of the Sine of the Angle of Refraction: For, if the Ray IC, which is ſuppoſed parallel to the refracting Surface, be refracted, at its Incidence on the denſer *Medium* at C, into the Line CV, the Line mV or Cp ſhall repreſent the perpendicular Motion generated by the Attraction; and C*m*V ſhall be equal to the Angle of Incidence, and CV*m* or VCQ ſhall be equal to the Angle of Refraction: If therefore V be made the Centre, and a Circle be ſuppoſed to be drawn with the *Radius* VC; CV will be the Sine of the Angle of Incidence, and C*m* the Sine of the Angle of Refraction; but, by reaſon of the rectangular Triangle C*m*V, *m*V is equal to $\sqrt{CV^2 - Cm^2}$, that is, the perpendicular Motion generated by the Attraction of the denſer *Medium* is equal to the Square-root of the Difference of the Square of the Sine of the Angle of Incidence and of the Square of the Sine of the Angle of Refraction.

That this Corollary may be the better remembered, let I and R be put for theſe Sines, and M for the Motion generated by Refraction, and the Æquation will ſtand thus $M = \sqrt{I^2 - R^2}$.

COROL. 2. When the Ray moves the contrary way, from the denſer *Medium* into the rarer, as from V to C, the perpendicular Motion, which is deſtroyed in Refraction by the Attraction of the denſer *Medium*, will here alſo be always equal to the Square-root of the Difference of the Square of the Sine of the Angle of Refraction, and of the Square of the Sine of the Angle of Incidence.

For it is obvious, that in this Caſe the attractive Force of the denſer *Medium* muſt deſtroy juſt as much Motion as it generated when the Ray moved the contrary way; and therefore, putting M for the perpendicular Motion which is deſtroyed, V*m* or *p*C; and I for the Sine of Incidence V*p* or C*m*, and R for the Sine of the Angle of Refraction CV: By reaſon of the rectangular Triangle C*m*V, we ſhall have $M = \sqrt{R^2 - I^2}$

Corol. 3. The Velocity of Light, after Refraction, is to the Velocity of Incidence, as the Sine of Incidence to the Sine of Refraction.

Firſt, Let the Light move from a rarer *Medium* into a denſer one, and let AC repreſent the Courſe and Velocity of any incident Ray AC, and C*v* the Courſe and Velocity of the refracted Ray C*v*; by Reaſon of the ſimilar Triangles C*v*P and CEF; *v*C : EC :: *v*P : EF; but *v*C is the Velocity of the Light after Refraction, and EC or AC the Velocity at Incidence, and *v*P (= C*d* or AD) is the Sine of Incidence, and EF the Sign of Refraction; therefore the Velocity, after Refraction, is to the Velocity of Incidence, as the Sine of Incidence to the Sine of Refraction.

Secondly, The ſame Corollary holds true, when the Ray moves the contrary way, from the denſer *Medium* into the rarer. For, From what has been ſaid, if vC repreſent the Courſe and Velocity of any Incident Ray, CA ſhall repreſent the Courſe and Velocity of the refracted Ray; but CA is equal to CE, and becauſe of the ſimilar Triangles CEF and CvP, CE, or CA, the Velocity of of the refracted Ray, is to vC, the Velocity of the Incident Ray, as EF, the Sine of the Angle of Incidence, is to vP or C*d* or AD, the Sine of the Angle of Refraction.

COROL. 4. The Velocity of Light after Refraction is always the ſame, with whatever Obliquity the Rays are incident.

This Corollary is a manifeſt Conſequence of the former one; for, if the Velocity, after Refraction, be called V, the Velocity of Incidence v, the Sine of Incidence I, and the Sine of Refraction R, by laſt Corollary, we ſhall have $V : v :: I : R$; whence $V = v\frac{I}{R}$; but v being the Velocity of the incident Ray, is a given fixed Quantity; therefore V, the Velocity after Refraction, is as $\frac{I}{R}$, that is, in proportion to the Sines which meaſure the Refraction of the Bodies; which is a conſtant and invariable *Ratio*.

A *fourth Phænomenon* of Refraction is, that the refracting Forces are always proportional to the Denſities of the Bodies, excepting ſo far as they partake more or leſs of ſulphureous oily Particles, and thereby have their refractive Powers made more or leſs.

This is ſo manifeſt a Conſequence of Attraction, that it ſcarce needs any Proof or Illuſtration. For the denſer the Body is, it muſt have the more attracting Matter in it; and, of conſequence, muſt refract the Light in that Proportion: This may be illuſtrated by the Attraction of Gravity, which always acts in proportion to the Denſity of the gravitating Body. But, when the refracting Body abounds with ſulphureous, oily and inflamable Parts, the Attraction, and conſequently the Refraction, will be ſtronger or weaker in proportion to the Quantity of theſe ſulphureous oily Particles; for, as Light congregated by a Burning-glaſs, acts moſt upon ſulphureous Bodies to turn them into Fire and Flame, ſo, ſince all Action is mutual, Sulphurs ought to act moſt upon Light to attract, refract, and reflect its Rays.

If therefore the Denſities of Bodies are equal, the Powers of Refraction will be as the Quantities of fat ſulphureous Particles: If the Quantity of ſulphureous Particles are equal, theſe Powers will be as the Denſities of the Bodies; and, if neither are equal, they will be in a compound Proportion of the Quantities of Sulphur and the Denſities: And as this is agreeable to Experience, ſo it is alſo an obvious Conſequence of that Attraction we have ſo long dwelt on.

§ 27. By what Law this attractive and repulſive Power operates in refracting and reflecting the Rays of Light, is not ſo eaſy to determine exactly, for want of ſufficient *Data*, founded on Experiments. This much however is certain, that as Attraction is ſtronger in ſmall Magnets than in great ones, in proportion to their Bulk, and Gravity is greater in the Surfaces of Small Planets than in thoſe of great ones, in proportion to their Bulk; and ſmall Bodies are agitated much more by electric Attraction than great ones; ſo the Smallneſs of the Rays of Light may contribute very much to the Power of the Agent by which they are refracted and reflected.

It is further certain, that this attractive Power which acts upon Light is infinitely ſtronger than the Power of Gravity: This will appear, if we conſider that Sir ISAAC NEWTON has demonſtrated, that all Bodies attract one another by the Force of Gravity, and that the attractive Forces of two homogeneal Spheres, upon Particles of Matter placed very near their Surfaces, are to each other in proportion as the Diameters of the Spheres; that is to ſay, if a refracting *Medium* be ſpherical, and of the ſame Denſity as the Earth, the Earth's Force of Attraction near its Surface, will exceed the *Medium*'s Force near its Surface, as much as the Diameter of the Earth exceeds the Diameter of the *Medium*, or almoſt infinitely with reſpect to human Conceptions. Yet we obſerve, that a Cannon-Ball juſt ſhot from the Mouth of a Cannon, is ſcarce ſenſibly deflected towards the Earth by its Attraction, and the leaſt Particle of the Ball, if it was ſeparate from the reſt, would be no more deflected than the whole; becauſe Gravity makes Bodies of all Sorts and Sizes deſcend with the ſame Swiftneſs, by affecting them alike, whether joined or ſeparated. Therefore a Particle of Light, which, as has been ſhewn, moves, I may ſay, infinitely quicker than a Cannon-ball, would be infinitely leſs bent than the Particle of the Ball by the Attraction of the whole Earth, and ſtill infinitely leſs than this laſt bending, by the Attraction of the ſpherical *Medium*, which was ſhown to be infinitely weaker than that of the Earth. But, in fact, we find it is far otherwiſe; a Ray of Light is very ſenſibly bent or refracted by the Action of the *Medium*; and therefore it muſt be affected by ſome other Power of the *Medium*, which, near its Surface, is infinitely ſtronger than the Power of Gravity: And, tho' we are not able to determine the exact

Law of this refractive Power, or the Degrees of its Force at given Diſtances from the refracting Surface; yet, ſince we find that the Effects of Gravity, which decreaſe as the Squares of the Diſtances from the Centre increaſe, are very ſenſible at great Diſtances, we may conclude, that the refractive Power of a *Medium*, which, at its Surface, we find is infinitely ſtronger than Gravity, and yet vaniſhes at a very ſmall Diſtance from it, decreaſes much quicker, or in a much greater proportion than Gravity does.

§ 28. 7. The *Laſt* Property of Light which I ſhall mention conſiſts in the Diverſity of its Rays; for Light is not all ſimilar and homogeneal, but compounded of heterogeneal and diſſimilar Rays, ſome of which in like Incidences being more refrangible, and others leſs refrangible; and thoſe which are moſt refrangible are alſo moſt reflexible, and according as they differ in Refrangibility and Reflexibility, they are endowed with a Power of exciting in us Senſations of different Colours.

§ 29. This wonderful Property of Light was, in the Year 1666, firſt diſcovered by the incomparable NEWTON, and afterwards publiſhed in the *Philoſophic Tranſactions*, *anno* 1672, where he alſo gave a ſmall Specimen of the Experiments he made for confirming his

Doctrine; but, at that Time, there were ſeveral learned Men who, being prejudiced in favour of other Theories, could not at firſt reliſh this new Doctrine, nor the Experiments and Reaſonings on which it was founded; and therefore formed Objections againſt it. All which NEWTON anſwered ſo effectually, that no Place was left for any Doubt or Difficulty, in ſo much that the learned GASTON PARDEES himſelf, tho' one of his principal Adverſaries, was ſo candid as to acknowledge, in his laſt Reply, that he was then intirely ſatisfied with his Doctrine. His Words are: *Omnino mihi ſatisfecit noviſſima Reſponſio a Domino* NEWTONO *ad meas inſtantias data; noviſſmus ſcrupulus, qui mihi hærebat circa experimentum crucis penitus fuit exemptus; atque nunc plane ex figura ipſius intelligo, quod non intellexeram ante; experimentum peractum cum fuerit iſto modo, nil habeo quod in eo deſiderem amplius.* And this I here take notice of to the Honour of this learned Philoſopher, who hereby has ſet us an Example of yielding to Truth, and avoiding vain Diſputations and endleſs Wranglings, worthy of our Imitation.

After that, in the Year 1704, the ſame great Man propoſed the ſame Doctrine more fully, in his beautiful Treatiſe of Optics, and confirmed it with great Variety of convincing Experiments; the reading of which we muſt therefore recommend to all thoſe who would be fully ſatisfied in the Nature of Light and Colours; for, before him, all the World believed that Light was ſimple and uniform, without any Difference or Variety in its Parts, and that Colours were nothing elſe than certain Changes or Modifications of Light cauſed by Refractions, Reflections and Shaddows; ſo that they aſcribed the Difference of Colours intirely to the different Textures of Bodies producing different Modifications in the Rays of Light, and not to any original Difference in the Rays themſelves, which they ſuppoſed perfectly homogeneal and ſimilar: But this great Philoſoper, to whom we are indebted for almoſt every Thing that we know with certainty concerning the Nature of Light and Colours, has demonſtrated beyond all Diſpute,

§ 30. 1*mo*, That Lights which differ in Colour differ alſo in Degrees of Refrangibility.

2*do*, That the Light of the Sun, notwithſtanding its uniform Appearance, conſiſts of Rays differently refrangible.

3*tio*, That thoſe Rays, which are more refrangible than others, are alſo more reflexible.

4*to*, That, as the Rays of Light differ in Degrees of Refrangibility and Reflexibility, ſo they alſo differ in their Diſpoſition to exibit this or that particular Colour; and that Colours are not Qualifications of Light, derived from Refractions or Reflections of natural Bodies, as was generally believed, but original and connate Properties, which, in divers Rays are divers, ſome Rays being diſpoſed to exhibit a red Colour, and no other, ſome a Yellow, and no other, ſome a Green, and no other, and ſo of the Reſt of the priſmatic Colours. Nor are there only Rays proper and particular to the more eminent priſmatic Colours, but even to all their intermediate Gradations.

5to, That the Light of the Sun conſiſts of Violet-making, Indigo-making, Blue-making, Green-making, Yellow-making, Orange-making, and Red-making Rays; and all theſe are different in their Degrees of Refrangibility and Reflexibility; for the Rays which produce red Colours are leaſt refrangible, and thoſe that make the Violet the moſt, and the reſt are more or leſs refrangible as they approach either of theſe Extremes, in the Order we have mentioned them; that is, Orange is leaſt refrangible next to Red, Yellow next to Orange, and ſo on: So that to the ſame Degree of Refrangibility there ever belongs the ſame Colour, and to the ſame Colour the ſame Degree of Refrangibility; and this Analogy betwixt Colours and Refrangibility is very perciſe an dſtrick, the Rays always either exactly agreeing in both or proportionally differing in both: For,

6to, Every homogeneal Ray, conſidered apart, is refracted according to one and the ſame Rule; ſo that its Sine of Incidence is to its Sine of Refraction in a given *Ratio*; that is, every different coloured Ray has a different *Ratio* belonging to it; what thoſe *Ratio's* are, NEWTON has alſo demonſtrated by Experiments: For Inſtance, if an heterogeneal white Ray of the Sun emerges out of Glaſs into Air, or, which is the ſame Thing, if Rays of all Colours be ſuppoſed to ſucceed one another in the ſame Line, and their common Sine of Incidence in Glaſs be divided into 50 equal Parts, then the Sines of Refraction into Air, of the leaſt and moſt refrangible Rays, will be 77 and 78 ſuch Parts reſpectively; and ſince every Colour has ſeveral Degrees, the Sines of Refraction of all the Degrees of Red will have all intermediate Degrees of Magnitude from 77 to $78\frac{1}{8}$; of all the Degrees of Orange from $77\frac{1}{8}$ to $77\frac{1}{5}$; of Yellow from $77\frac{1}{5}$ to $77\frac{1}{3}$; of Green, from $77\frac{1}{3}$ to $77\frac{1}{2}$; of Blue, from $77\frac{1}{2}$ to $77\frac{2}{3}$; of Indigo, from $77\frac{2}{3}$ to $77\frac{7}{9}$, and of Violet, from $77\frac{7}{9}$ to 78.

7mo, The Species of Colour and Degree of Refrangibility and Reflexibility proper to any particular ſort of Rays is not mutable by Refraction, nor by Reflection, from natural Bodies, nor by any other Cauſe that has yet been obſerved. When any one Sort of Rays hath been well parted from thoſe of other Kinds, it hath afterwards obſtinately retained its Colour, notwithſtanding all Endeavours to change it. NEWTON refracted it with Priſms, reflected it with Bodies, which in Day-light were of other Colours; intercepted it with the coloured Film of Air interceding two compreſſed Plates of Glaſs; tranſmitted it thro' coloured *Mediums*, and thro' *Mediums* irradiated with other Sorts of Rays, and diverſly terminated it; and yet could never produce any new Colour out of it: It would, by contracting or dilating, become more briſk or faint, and by the Loſs of many Rays, in ſome Caſes, become very obſcure and dark; but he could never ſee it changed *in Specie*.

8vo, Yet ſeeming Tranſmutations of Colours may be made, where there is any Mixture of divers Sorts of Rays; for, in ſuch Mixtures, the component Colours appear not, but, by their mutual alloying each other, conſtitute a middling Colour, and therefore, if by Refraction or any other of the aforeſaid Cauſes, the difform Rays latent in ſuch a Mixture be ſeparated, there ſhall emerge Colours different from the Colour of the Compoſition: Which Colours are not new generated, but only made apparent by being parted; for, if they be again intirely mixed and blended together, they will again compoſe that Colour which they did before Separation. And, for the ſame Reaſon, Tranſmutations made by the conveening of divers Colours are not real; for, when the difform Rays are again ſevered, they will exhibit the very ſame Colours which they did before they entered the Compoſition, as we ſee blue and yellow Powders, when finely mixed, appear to the naked Eye green; and yet the Colours of the component Corpuſcles are not thereby really tranſmuted, but only blended; for, when viewed with a good Microſcope, they ſtill appear blue and yellow interſperſedly.

9no, There are therefore two Sorts of Colours, the one original and ſimple, the other compounded of theſe; and all the Colours in the Univerſe which are made by Light, and depend not on the Power of Imagination, are either the Colours of Homogeneal ſimple Light, or compounded of theſe mixed together in certain Proportions. The Colours of ſimple homogeneal Light, as we have ſaid before, are Violet, Indigo, Blue, Green, Yellow, Orange and Red, together with an indefinite Variety of intermediate Gradations: The Colours of compounded Light are different according as it is differently compounded of theſe ſimple Rays, mixed in different Proportions; thus, a

Mixture of Yellow-making Rays and Blue-making Rays exhibits a green Colour, and a Mixture of red and yellow Rays makes an orange Colour; and, in general, any Colour the ſame in Specie with the primary ones, may be produced by the Compoſition of the two Colours next adjacent in the Series of Colours generated by the Priſm, whereof the one is next moſt refrangible, and the other next leaſt refrangible. But thoſe which are ſituated at too great a Diſtance do not ſo; Orange and Indigo produce not the intermediate Green, nor Scarlet and Green the intermediate Yellow.

1*omo*, But the moſt ſurpriſing and wonderful Compoſition of Light is that of Whiteneſs; there is no one Sort of Rays which alone can exhibit this; it is ever compounded, and, to its Compoſition, are requiſite all the aforeſaid primary Colours, mixed in due Proportion: For, if the Colours made by a Priſm are, by means of a *Lens*, made to converge, and thereby be again mixed as they were in the Light before it was incident upon the Priſm, a Light will be reproduced intirely and perfectly white, and not at all ſenſibly differing from the direct Light of the Sun, unleſs when the Glaſſes are not ſufficiently clear; for then they will a little incline the Light to their Colour. Hence therefore it comes to paſs, that Whiteneſs is the uſual Colour of Light; for Light is a confuſed aggregate of Rays endowed with all Sorts of Colours, as they were promiſcuouſly darted from the various Parts of luminous Bodies; and of ſuch a confuſed aggregate, as I ſaid, is generated Whiteneſs, if there be a due Proportion of the Ingredients; but, if any one predominate, the Light muſt incline to that Colour, as it happens in the blue Flame of Brimſtone, the yellow Flame of Tallow, the green Flame of Copper opened with Sublimate, the white Flame of Camphire, and the various Colours of the fixed Stars.

And as Whiteneſs is produced by mixing the Colours ſevered by Priſms, ſo it may alſo be produced by mixing the coloured Powders which Painters uſe. But it muſt be conſidered, that all coloured Powders do ſuppreſs and ſtop in them a very conſiderable Part of the Light by which they are illuminated; for they become coloured, as ſhall be ſhewn below, by reflecting the Light of their own Colour more copiouſly, and that of all other Colours more ſparingly: And yet they do not reflect the Light of their own Colours ſo copiouſly as white Bodies do. If Red-lead, for Inſtance, and a white Paper be placed in the red Light of the coloured *Spectrum*, made in a dark Chamber by the Refraction of a Priſm, the Paper will appear more lucid than the Red-lead, and therefore reflects the Red-making Rays more copiouſly than the Red-lead doth; and, if they be held in the Light of any other Colour, the Light reflected by the Paper will exceed the Light reflected by the Red-lead in a much greater Proportion: And the like happens in Powders of other Colours; and therefore, by mixing ſuch Powders, we are not to expect a ſtrong and full White, but ſome duſky obſcure one, ſuch as might ariſe from a Mixture of Light and Darkneſs, or from White and Black, that is, a Grey or Dun, or Ruſſet-brown (for as Whiteneſs ariſes from a copious Reflection of all Sorts of Rays, as they were promiſcuouſly darted from the luminous Body, ſo Blackneſs ariſes from a Suffocation and Suppreſſion of the incident Light, which being ſtopt in the black Body is not reflected) and ſuch dark Whites may be produced by mixing coloured Powders. Thus one Part of *Minium* and 5 Parts of *viride Æris* compoſe a dun Colour, like that of a Mouſe; for theſe two Colours were ſeverally ſo compounded of others, that in both together were a Mixture of all Colours: And leſs Red-lead muſt be uſed than *viride Æris*, becauſe of the Fullneſs of its Colour; but the Experiment will ſucceed better, if to Orpiment be added a little full bright Purple uſed by Painters, until the Orpiment ceaſe to be yellow, and become of a pale Red, and that Red be diluted by adding a little *viride Æris*, and a little more blue Biſe than *viride Æris*, until it becomes of ſuch a grey or pale White as verges to no one of the Colours more than to another: For thus it becomes of a Colour equal in Whiteneſs to that of Aſhes, or Wood newly cut, or of a Man's Skin; but to aſſign the Proportions of theſe Ingredients accurately may be difficult, by Reaſon of the different Goodneſs of Powders of the ſame Kind.

Now, conſidering that theſe grey and dun Colours may be alſo produced by mixing Whites and Blacks, and by conſequence differ from perfect Whites, not in Species of Colour, but only in Degree of Luminouſneſs, it is manifeſt, that there is nothing more requiſite to make them perfectly White than to increaſe their Light ſufficiently: And, on the contrary, if by increaſing their Light they can be brought to perfect Whiteneſs, it will thence alſo follow, that they are of the ſame Species of Colour with the beſt Whites; and this has been tried as follows:

Rub ſome of the above mentioned grey Powder thickly upon the Floor, where the Sun ſhines upon it; and by it, in the Shadow, lay a Piece of white Paper of the ſame Bigneſs; at the Diſtance of about 12 Feet, the Powder will appear intenſely white, ſo as even to tranſcend the Paper itſelf in Whiteneſs, eſpecially if the Paper be a little ſhaded from the Light of the Clouds; and then the Paper, compared with the Powder, will appear of ſuch a grey Colour as the Powder had done before; but, by increaſing or diminiſhing the Lights wherewith the Paper and Powder are illuminated, they may be brought to that Proportion that they ſhall both appear exactly alike in Whiteneſs, in ſo much that being both good Whites, no Body can ſay which is beſt, nor wherein their Colours differ. Now, if we conſider that this White of the Powder in the Sun-ſhine is compounded of the Colours which the component Powders have in the ſame Sun-ſhine, we muſt acknowledge that perfect Whiteneſs is compounded of Colours.

11*mo*, As Whiteneſs is produced by a copious Reflection of Rays of all Sorts of Colours, when there is a due Proportion in the Mixture, as in the direct Light of the Sun; ſo, on the contrary, Blackneſs is produced by a Suffocation and Abſorption of the incident Light, which being ſtopped and ſuppreſſed in the black Body, is not reflected outward, but enters the Body and is often reflected and refracted within the Body, until it be ſtifled and loſt. Whence it is eaſy to ſee, why all Shadows, even thoſe caſt upon white Paper, or other white Bodies, are always more or leſs black, according as leſs or more Light is reflected upon them from other Bodies about; for Shadow and Blackneſs are near a-kin, and Shadow, we know, is but a Privation of Light; Blackneſs therefore ſeems to proceed from the want of Rays reflected from the black Body to the Eye; but the Bodies we call black, as Marble, Jet, *&c.* are not perfectly ſo; for, if they were, we ſhould not ſee them at all.

From this alſo we may ſee, why, of all Bodies, black ones are ſooneſt and moſt ſtrongly heated, and take fire ſooneſt; whereas, of all Bodies, white ones are lateſt and leaſt heated, and are longeſt in taking fire; for, by the frequent Reflections and Refractions which the Light ſuffers within the black Body, its Parts are ſoon put into thoſe vibratory Motions wherein Heat and Fire conſiſt; but by one Act of Reflection white Bodies ſend back all the Light incident upon them, and therefore are not ſo quickly nor ſo ſtrongly heated, and are much longer in taking fire.

Agreeable to this Doctrine, we find, that black Cloth dries much ſooner than white; black garden Walls are hotter than white ones; the Fire ſtruck from a Flint by Steel preſently kindles a black half burnt Rag, but does not at all kindle a white Rag; black Charcoal burns preſently, whereas the ſame Wood, before it is reduced to Charcoal, does not kindle but with a ſtronger Fire; Gun-powder eaſily takes Fire, by reaſon of the black Charcoal that enters its Compoſition; whereas, without the Charcoal, it would not burn ſo eaſily; a Candle whoſe Wick is burnt to Blackneſs is eaſily lighted after it has been put out, but a Candle that has never been lighted does not take Fire ſo ſoon. The famous Mr. BOYLE made a concave *Speculum* of black Marble, but he could not, in a long Time, ſet a Piece of Wood on fire with it; but white Bodies reflect almoſt all the Light incident upon them; and therefore concave *Specula* made of white Metals burn vehemently in their *Focus*, where the Rays are congregated; but, if ſuch a *Speculum* be blacked over with the Smoak of a Lamp, it will not then reflect any ſenſible Heat or Light to the *Focus*, nor will it rarify the Mercury in the Thermometer when placed there; but the *Speculum* itſelf will ſoon be heated by the Rays that are ſtopt and ſtifled at its Surface. It is for this Reaſon, that black Earths, like other black Bodies, are much hotter than white Earths; but white Earths, by reflecting moſt of the incident Light into the Air, heats it extremely; whence the Iſland *Ormus* is ſo vehemently hot from the ſtrong Reflection that is made by its white Mountains.

Theſe Things being conſidered, the Manner how Colours are produced by the Priſm is evident; for of the Rays conſtituting the incident Light, ſince thoſe which differ in Colour, proportionally differ in Refrangibility, they, by their unequal Refractions, muſt be ſevered and diſperſed into an oblong Form, in an orderly Succeſſion, from the leaſt refracted Scarlet to the moſt refracted Violet: And for the ſame Reaſon it is, that Objects, when looked upon thro' a Priſm, appear coloured; for the difform Rays, by their unequal Refractions, are made to diverge towards ſeveral Parts of the *Retina*, and there expreſs the Images of Things coloured, as in the former Caſe they did the Sun's Image upon a Wall. And by this Inequality of Refractions they become not only coloured but alſo very confuſed and indiſtinct.

Why the Colours of the Rain-bow appear in falling Drops of Rain is alſo from hence evident; for thoſe Drops which refract the Rays, diſpoſed to appear Purple, in greateſt Quantity to the Spectator's Eye, refract the Rays of other Sorts ſo much leſs, as to make them paſs beſide it; and ſuch are the Drops on the Inſide of the primary Bow, and on the outſide of the ſecundary or exterior one. And thoſe Drops which refract in greateſt Plenty the Rays apt to appear red toward the Spectator's Eye, refract thoſe of other Sorts ſo much more as to make them paſs beſide it; and ſuch are the Drops on the exterior Part of the primary Bow, and the interior Part of the ſecundary Bow.

The odd *Phænomena* of an Infuſion of *Lignum Nephriticum*, Leaf-gold, Fragments of coloured Glaſs, the Feathers of a Dove's Neck, and a Peacock's Tail, and ſome other tranſparently coloured Bodies, appearing, in one Poſition, of one Colour, and of another in another, are, on theſe Grounds, no longer Riddles; for thoſe are Subſtances apt to reflect one Sort of Light and tranſmit another; as may be ſeen in a dark Room by illuminating them with ſimilar or uncompounded Light; for then they appear of that Colour only with which they are illuminated; but yet in one Poſition more vivid and luminous than in another, accordingly as they are diſpoſed more or leſs to reflect or tranſmit the incident Colour.

From hence alſo is manifeſt, the Reaſon of an unexpected Experiment which Mr. HOOK, in his *Micrographia*, tells us, he made with two Wedge-like tranſparent Veſſels, filled the one with a red, the other with a blue Liquor, namely, that tho' they were ſeverally tranſparent enough, yet, both together, became opaque; for, if one tranſmitted only red, and the other only blue, no Rays could paſs thro' both.

Many more Inſtances of this Nature might be added; but I ſhall conclude with this general one, namely, that the Colours of all natural Bodies have no other Origin than that they are variouſly qualified to reflect one Sort of Light in greater Plenty than another. This hath been experimented in a dark Room by illuminating thoſe Bodies with uncompounded Light of divers Colours; for, by that means, any Body may be made to appear of any Colour; they have there no appropriate Colour, but ever appear of the Colour of the Light caſt upon them; but yet with this Difference, that they are moſt briſk and vivid in the Lights of their own Day-light Colour: *Minium* appeareth there of any Colour indifferently with which it is illuſtrated, but yet moſt luminous in red; and ſo Biſe appeareth indifferently of any Colour with which it is illuſtrated, but yet moſt luminous in blue; and therefore *Minium* reflecteth Rays of any Colour, but moſt copiouſly thoſe endowed with red; and conſequently, when illuſtrated with Day-light, that is, with all Sorts of Rays promiſcuouſly blended, thoſe qualified with red ſhall abound moſt in the reflected Light, and by their Prevalence cauſe it to appear of that Colour. And, for the ſame Reaſon, Biſe reflecting blue moſt copiouſly ſhall appear blue, by the Exceſs of thoſe Rays in its reflected Light; and the like of other Bodies. And that this is the intire and adequate Cauſe of their Colour, is manifeſt; becauſe they have no Power to change or alter the Colours of any Sort of Rays incident a-part, but put on all Colours indifferently with which they are enlightened; and therefore, were there no Diverſity of Rays, there could be no Diverſity of Colours, and all the Bodies in the World would be of one ſimilar Colour.

This is a Sketch of what NEWTON hath diſcovered on this Head; for a full Demonſtration whereof I muſt refer the Reader to that ſurpriſingly beautiful Treatiſe of Optics wrote by himſelf; for it is impoſſible to ſeparate the Parts of this Work from one another, without Diſadvantage to them, or to ſum them up in leſs Room, without loſing many Things both uſeful and entertaining. That great Philoſopher having, in his *Principia*, ſhewn how far Numbers and Geometry would go in Natural Philoſophy, has, in his Optics, manifeſted to the World to what ſurpriſing Height even vulgar Experiments, duly managed and carefully examined, in ſuch Hands, may advance it; for, to the Honour of this great Man, it is to be obſerved, that he was led to all his Diſcoveries in Optics, as he himſelf tells us, by obſerving the oblong Form of the Sun's coloured Image caſt upon the

Wall of a dark Room, by means of a Priſm placed at a Hole in the Window-ſhut. This was an Experiment at that Time well known to all Naturaliſts; but it was reſerved to NEWTON to diſcover, and, by his ſuperior Skill in Geometry, to demonſtrate, againſt all his Adverſaries, that this Image, on the old Principle of an equal Refraction of all the Rays, ought to be circular; and conſequently, that this oblong Form proceeded from a different Refrangibility of the Rays whereof the Sun's Beam conſiſted, by Means of which Refrangibility the Rays of different Colours were ſeparated from each other, and exhibited a Part in the oblong coloured *Spectrum*: And, having made this fundamental Diſcovery, he alſo confirmed it by Experiments, and was thereby led to contrive many other Experiments by which he has opened the whole Myſtery of Light and Colours; as may be ſeen in the aforeſaid Treatiſe of Optics.

§ 31. This Difference of Refrangibility in the Particles of Light argues a Difference likewiſe in their Magnitude; for, ſince one and the ſame Cauſe, *viz.* the Attraction of the Glaſs, acting upon them all with equal Force, and under like Circumſtances, produces unequal changes in the Directions of their Motions, it muſt needs be that they move with unequal Forces; and conſequently, that their

Quantities of Motion are unequal; which Inequality of Motion can ariſe from nothing elſe but the different Size of the Particles, in caſe they all move equally ſwift, and are all equally ſolid, as is generally ſuppoſed: Conſequently, the Particles of Light, which differ as to Colour, differ alſo in Magnitude; thoſe of Violet being ſmalleſt, and the Particles of other Colours increaſing continually one above another, as they are more and more removed from the Violet, and approach nearer to the Red, whoſe Particles are the largeſt of all.

§ 32. And here it will not be improper to obſerve, that the red Particles, being of all the largeſt, they muſt, on that Account, act with the greateſt Force, and excite the ſtrongeſt Vibrations in the nervous Coat of the Eye; which may be one Reaſon why Reds produce a ſtrong Senſation, and are found to be more offenſive to the Eyes than any other Colour whatever; and the violet Particles being the leaſt, muſt, on that Account, excite the weakeſt Vibrations, and conſequently produce only a weak, faint, dark Colour; but the green Particles, being of a Size equally diſtant from both theſe extremes, muſt, by exciting Vibrations of a middling Strength, produce a Colour ſufficiently ſtrong and bright, while at the ſame time it does not offend the Eye by its too great Strength and Vivacity: And this is the Reaſon why green Colours have in all Times been eſteemed uſeful to comfort, ſtrengthen and preſerve the Sight.

§ 33. This Doctrine receives ſtill ſome further Confirmation from a remarkable Experiment which I find taken notice of by the famous Monſ. *de la* HIRE, in his Diſſertation *ſur les differens Accidens de la Vue*, publiſhed in the Year 1694; the Experiment is as follows:

After having looked a ſhort while at the Sun, ſhut your Eyes, and you ſhall, for ſome time after they have been ſhut, ſtill continue to ſee his Image, whoſe Brightneſs diminiſhes little by little, and puts on ſucceſſively Colours leſs and leſs bright and lively; for, immediately after your Eyes have been ſhut, the Image appears of a red Colour, but, in keeping the Eye ſtill ſhut, it appears yellow, then green, afterwards blue, and at laſt violet; but if the Eyes are kept open, theſe Colours will appear different, becauſe, compared with others which are ſeen at the ſame time in Bodies that ſurround them, and becauſe of their Mixture with them, as is eaſy to underſtand; for it is certain that what appears white, for Inſtance, when the Ground is black, may appear black or brown when the Ground is white; and theſe Colours which appear yellow or blue, when the Eyes are ſhut, will appear green, if one looks at a blue or yellow Body; for Experience teaches us, that a Mixture of thoſe two Colours forms a Green.

Now, theſe apparent Colours which are ſeen after having looked at the Sun, can proceed from nothing but the too violent Agitation excited in the *Retina*, by the Rays of Light, and their Continuance for ſome time after the Eyes are ſhut, can flow from nothing, but that theſe Tremors or Agitations are of a laſting Nature and do not preſently periſh, but continue for ſome time, ſtill growing weaker and weaker, till they at laſt vaniſh: And, ſince the Colours connected to theſe Tremors or Vibrations are ſucceſſively changed, as the Vibrations grow weaker, from Red to Yellow, from Yellow to Green, from Green to Blue, and from Blue to Violet, in the Priſmatic order; it follows that the Senſation of Red proceeds from a ſtrong Agitation excited in the *Retina*, that of Yellow from a weaker, and that of Green, Blue and Violet from others ſtill weaker and weaker; and conſequently, that the Red-making Rays are the largeſt, the Violet-making the leaſt, and the ſeveral intermediate Sorts of Rays of ſeveral intermediate Degrees of Magnitude; as has been above explained.

§ 34. As this Doctrine is agreeable to Reaſon, ſo it alſo ſeems to have been the Opinion of our great Philoſopher. His Words are: " Nothing is more requiſite for produ-" cing all the Variety of Colours, and De-" grees of Refrangibility, than that the Rays " of Light be Bodies of different Sizes, the " leaſt of which may make Violet, the weakeſt " and darkeſt of the Colours, and be more " eaſily diverted by refracting Surfaces from " their right Courſe; and the reſt, as they are " bigger and bigger, may make the ſtronger " and more lucid Colours, Blue, Green, Yellow " and Red, and be more and more difficultly " diverted " (NEWTON *Optic. Quer.* 29.)

§ 35. To this it has been lately objected, by the ingenious Mr. MELVILL, in the *Edinburgh Eſſays Phyſical* and *Literary*, *vol.* ii. that, " if there be any Analogy between " Gravity and the refractive Power, it will " produce equal perpendicular Velocities in all " Particles, whatever their Magnitude or " Denſity be, and ſo all Sorts of Rays would " be ſtill equally refrangible; whence he thinks " it a more probable Opinion, that the differ-" ently coloured Rays are propagated with " different Volocities from the luminous " Body, the Red with the greateſt, Violet with " the leaſt, and the intermediate Colours

" with intermediate Degrees of Velocity."
But the Anſwer to this is eaſy: For,

Firſt, Tho' there is ſome Analogy between Gravity and this refractive Power, both being the Effects of Attraction, yet the Laws by which theſe Attractions are governed, are ſo widely different, that there cannot be the leaſt Doubt, with any body who ſhall conſider what has been already ſaid of theſe Laws, that tho' Gravity produces perpendicular Velocities, which to Senſe are equal in all Bodies, whatever their Magnitude or Denſity be; yet, if the Rays of Light be Bodies of different Sizes, the attractive Power of the refracting *Medium*, which, near its Surface, is infinitely ſtronger than Gravity, and yet vaniſhes at a very ſmall Diſtance from it, muſt in them produce different perpendicular Velocities, ſtill the greater Velocity the ſmaller the Particle be. And as this is a ſufficient Anſwer to the Objection formed againſt NEWTON's Doctrine, ſo, on the other Hand, the Hypotheſis which our Author himſelf embraces ſeems very improbable: For,

Secondly, It is a very difficult Matter to conceive how the Particles of Light, ſuppoſing them to be of the ſame Magnitude and Denſity, ſhould be emitted with different Velocities from the ſhining Body: They are ſuppoſed to be emitted from the ſhining Body by the vibrating Motion of the Parts of the Body, and ſo ſoon as they get beyond the Reach of its Attraction, they are ſuppoſed to be driven forwards with exceeding great Velocity by the repelling Force of the Body: But theſe Cauſes acting uniformly, ought to produce equal Velocities in all the Rays; nor does it ſeem poſſible to aſſign any other Cauſe whatever that ſhould make them move with different Velocities; for, to ſuppoſe that the ſame Cauſe acting uniformly ſhould produce different Effects on ſimilar Subjects, in ſimilar Circumſtances, to me ſeems not much leſs abſurd, than that any thing ſhould happen without any Cauſe at all.

Thirdly, Another Objection to this Hypotheſis ariſes from what our Author himſelf propoſes for examining his Theory. His Words are: " The Time which the extreme Violet " takes to move thro' any Space muſt be to " that which the Red takes as 78 to 77. If " *Jupiter* be ſuppoſed in a quadrate Aſpect " with the Sun, in which Caſe the Eclipſes of " his Satellites are moſt commodiouſly obſer" ved, his Diſtance from the Earth being nearly " equal to his Diſtance from the Sun, Light " takes about 41 Minutes of Time in paſſing " from him to the Earth; therefore the " laſt Violet Light which a Satellite reflects, " before its total Immerſion in the Shadow

“ of *Jupiter*, ought to continue to effect the
“ Eye for a 77th Part of 41′ or 32″, after
“ the Red, reflected at the ſame time, is
“ gone; that is, a Satellite, ſeen from the
“ Earth ought to change its Colour above half
“ a Minute before its total Immerſion, from
“ white to a livid greeniſh Colour, thence
“ into Blue, and, at laſt, vaniſh in Violet:
“ And the ſame *Phænomenon* ſhould take Place
“ in the time of Emerſion, by a contrary
“ Succeſſion of Colours, beginning with Red
“ and ending in White.” Then he adds, “
“ If this *Phænomenon* ſhould be actually per-
“ ceived by Aſtronomers, we ſhall have a
“ ſufficient direct Proof of the different Ve-
“ locities of the coloured Rays; for I ſee not
“ (ſays he) to what other Cauſe the *Phæno-*
“ *menon* could be rationally aſcribed; if it be
“ not, we may conclude, that Rays of all
“ Colours are emitted and reflected with one
“ common Velocity.”

So far this ingenious Gentleman, with whom I agree in every Particular; but muſt be forgiven to obſerve, that the Silence of all Aſtronomers, with regard to this *Phænomenon*, makes it evident, that it does not take place; for ſuch a remarkable *Phænomenon* could not have miſt been obſerved by them; and, if it had been obſerved, they no doubt, would have publiſhed it to the World when writing on that Subject;

Subject: Since therefore this *Phænomenon* does not take place, we may from thence ſafely conclude, that Rays of all Colours are emitted and reflected with one common Velocity, and that all the Variety of Colours, and Degrees of Refrangibility, proceed from nothing elſe but the different Sizes of the Particles of Light; agreeable to the *Newtonian* Doctrine above explained.

CHAP. II.

Of the Manner of Viſion, and the Uſe of the ſeveral Humours of the Eye.

SECT. I. HAVING, as breifly as was poſſible explained ſuch of the fundamental Properties of Light as may be of Uſe for underſtanding the Manner and manifold *Phænomena* of Viſion, the Order propoſed now leads us to conſider how Viſion is performed, to inquire into the Uſe of the ſeveral Parts of the Eye concerned therein, and to account for its various Conformations in various Animals.

For explaining Viſion, many Hypotheſes have been invented by Philoſophers. The Stoics imagined, that certain viſual Rays went from the Brain thro' the optic Nerve and Eye, and from thence to the Object, and there juſt like a blind Man's Staff, felt out the Figure, Colour and Dimenſion of the Object. CHRYSIPPUS was one of the great Patrons and Propagators of this Hypotheſis; but others of the ſame Sect thought, that nothing Material, ſuch as viſual Rays or Spirits went out of the Eye, but, which is yet more groſs and ridiculous, only a perceptive Power or Faculty, like what the Vulgar imagine to proceed from the Loadſtone, by which they ſuppoſe it acts upon Iron at a Diſtance.

The *Pythagoreans* believed, that there went ſome viſual Species out of the Eye to the Object, which, like a Ball thrown againſt a Wall, were immediately reflected back again from thence to the Eye, and ſo produced Viſion.

EPICURUS, LUCRETIUS, and LEUCIPPUS, aſſerted, that the Senſe of Viſion was produced by a continual ſucceſſive Emanation of material Images, which they ſuppoſed were conſtantly emitted to the Eye from the Object, and which, at their firſt Emiſſion, are very great, and decreaſe continually the further they go, till they arrive at ſuch a Smallneſs, as will permit them to enter the Eye, that the Mind may perceive them. DEMOCRITUS was alſo much of the ſame Opinion; only he thought that theſe Species or Images did not enter the Eye itſelf, but produced Viſion by falling on its ſmooth and equal Surface.

PLATO ſuppoſed, that, both from the Eye and the Object, there came ſubſtantial *Effluvia*, which, meeting with one another Midway, embraced one another, then returned, and made their Report to the Eye, and ſo to the Mind, for cauſing the Senſe of Seeing.

ARISTOTLE, that famous Philoſopher and firſt Founder of the Peripatetic Sect, after having refuted the Opinion of PLATO and the other Philoſophers that went before him, aſſerts, that Colours, which with him are Qualities of the Object, do move the tranſparent *Medium* as that does the Eye, and thereby communicates their Images to the Brain, or common Senſory: Yet GALEN, that great Diſciple of ARISTOTLE, from whom he borrowed moſt of his Philoſophy, rejects this Opinion, and rather embraces that of PLATO.

DES CARTES ſuppoſes Viſion is performed by bare Motion only, without any material Emanation from the Object; but only that the Light (which with him alſo is not a Body, but the Motion of the finer Parts of the *Medium*)

dium) moves the Eye juſt after the ſame Manner as the Object is ſuppoſed to have determined it, which Motion is continued along the optic Nerve up into the Brain, where it moves the Conarion, or *Glandula Pinealis*, with him the Seat of the Soul, and by that means produces internal Senſation, and enables the Soul to judge accordingly.

Theſe are the principal Opinions that have been invented for explaining Viſion. But it is impoſſible to put them in a full good Light without taking up too much Time, which we are unwilling to do, eſpecially ſince now they are all rejected as erroneous.

§ 2. That we may therefore give ſome more ſatisfying Account how this noble Senſe is produced, we muſt premiſe the following *Lemma*:

LEMMA.

Wherever the Rays which come from all the Points of any Object meet again in ſo many Points, after they have been made to converge by Refraction, there they will make a Picture of the Object upon any white Body on which they fall.

Demonstration. Let PR (Plare III. *Fig.* 22.) repreſent any Object without Doors, and AB be a *Lens* placed at a Hole in the Window-ſhut of a dark Chamber, whereby the

Rays that come from any Point Q of that Object are, by the refractive Power of the Glaſs, turned out of their ſtreight Courſe, and made to converge and meet again in the Point *q;* if a Sheet of white Paper be held at *q* for the Light there to fall upon it, the Picture of that Object PR will appear upon the Paper in its proper Shape and Colours. For as the Light which comes from the Point Q goes to the Point *q;* ſo the Light which comes from the other Points P and R of the Object will go to ſo many other correſpondent Points *p* and *r* (as is manifeſt from the Laws of Refraction above explained.) So that every Point of the Object ſhall illuminate a correſpondent Point of the Picture, and thereby make a Picture like the Object in Shape and Colour, this only excepted, that the Picture ſhall be inverted. And this is the Reaſon of that vulgar Experiment of caſting the Species of Objects from aboard upon a Wall or Sheet of white Paper in a dark Room; which is therefore an experimental Proof of the Truth of this *Lemma.*

§ 3. Now this Repreſentation of Objects upon a Sheet of white Paper, by means of a *Lens* placed at a Hole in the Window-ſhut of a dark Room, is perfectly ſimilar to what happens in our Eyes when we view Objects; for Viſion, in ſo far as our Eyes are concerned, conſiſts in nothing but ſuch a Refraction of the Rays of Light by the tranſparent Skins and Humours of the Eye, as is neceſſary to unite and bring together the Rays which come from the ſeveral Points of the Object in ſo many correſponding Points in the Bottom of the Eye, and there to paint the Picture of the Object upon the *Tunica Retina*, with which the Bottom of the Eye is covered; which Picture being propagated by Motion along the Fibres of the optic Nerve into the Brain, is the Cauſe of Viſion: For accordingly as theſe Pictures are perfect or imperfect, the Object is ſeen perfectly or imperfectly: If the Eye be tinged with any Colour (as in the Diſeaſe of the Jaundice), ſo as to tinge the Pictures in the Bottom of the Eye with that Colour, then all Objects appear tinged with the ſame Colour; if the Humours of the Eye, by old Age, decay, ſo as, by ſhrinking, to make the *Cornea* and chryſtalline Humour grow flatter than before, the Light will not be refracted enough, and, for want of ſufficient Refraction, will not converge to the Bottom of the Eye, but, to ſome Place beyond it, and, by conſequence, muſt paint in the Bottom of the Eye a confuſed Picture; and, according to the Indiſtinctneſs of this Picture, the Object will appear confuſed and indiſtinct. This is the Reaſon of the Decay of Sight in old Men, and ſhews why their Sight is mended by ſpectacles; for thoſe convex Glaſſes ſupply the Defect of

Plumpneſs in the Eye, and, by increaſing the Refraction, make the Rays converge ſooner, ſo as to conveen diſtinctly at the Bottom of the Eye, if the Glaſs have a due Degree of Convexity: And the contrary happens in ſhort-ſighted Men, whoſe Eyes are too plump; for the Refraction being now too great, the Rays converge and conveen in the Eyes before they come at the Bottom; and therefore the Picture made in the Bottom, and the Viſion cauſed thereby, will not be diſtinct, unleſs the Object be brought ſo near the Eye, as that the Place where the converging Rays conveen may be removed to the Bottom, or that the Plumpneſs of the Eye be taken off, and the Refractions diminiſhed by a concave Glaſs, of a due Degree of Concavity; or, laſtly, that by Age the Eye grows flatter, till it come to a due Figure; for ſhort-ſighted Men ſee remote Objects beſt in old Age, and therefore they are accounted to have the moſt laſting Eyes.

§ 4. Thus, in general, Viſion is performed. But, in order to underſtand how the ſeveral Humours of the Eye conduce to the forming of this Image or Picture, (ſee PLATE III. *Fig.* 23.) where Z is the Eye, and B *t*, B *s*, B *u*, *&c.* are Rays coming to the Eye from the Point B, of the Object ABC, placed at a convenient Diſtance before the Eye; of theſe Rays it is obvious, that the middle one B *t* being in the *Axis* of Viſion, muſt fall perpendicularly upon all the Humours of the Eye, as it paſſes thro' them to the *Retina*, and conſequently muſt move ſtreight forward to *b* in the Bottom of the Eye, without ſuffering any Refraction: But the other Rays, as B*s*, B*u*, *&c.* by falling obliquely upon the tranſparent *Cornea*, which being of equal Denſity with the aqueous Humour, muſt have the ſame refractive Power; I ſay, theſe other Rays, by falling obliquely upon the *Cornea*, which is denſer than the *Medium* of Air thro' which they paſſed, will be refracted towards the perpendicular; let therefore *hp* and *hp* be drawn perpendicular to the *Cornea*, at the Points of Incidence *s* and *u*, it is evident, that theſe Rays, by being refracted towards theſe Perpendiculars, will be made to approach one another, becauſe the Perpendiculars themſelves do ſo (for every body knows that Lines cutting a Circle perpendicularly do approach one another ſo as to meet at the Centre); and this is the firſt Refraction which the Rays ſuffer in falling upon our Eyes, by which they are brought nearer to one another, that more of them may paſs thro' the Pupil, and may not be loſt upon the *Uvea.*

A ſecond Refraction which thoſe Rays ſuffer, is in paſſing out of the aqueous Humour into the Cryſtalline; by which Refraction they are made to approach ſtill more to one another than before; for the Cryſtalline being denſer than the aqueous Humour, the Rays here alſo muſt be refracted towards the Perpendiculars *i* P, *i* P; but theſe Perpendiculars, becauſe of the convex circular Surface of the Cryſtalline, do approach one another; and therefore the Rays, which by Refraction are turned out of their ſtreight Courſe, and made to move towards theſe Perpendiculars, muſt alſo approach one another, and become more convergent: And this is the ſecond Refraction which the Rays ſuffer in moving thro' the tranſparent Humours of the Eye.

But there is yet a third Refraction which the Rays ſuffer in paſſing out of the cryſtalline into the vitreous Humour; for the cryſtalline Humour being more denſe than the vitreous, the Light, in paſſing from the Cryſtalline into this Humour, will be refracted from the Perpendiculars P *l*, P *l*: But, becauſe the Surface of this Humour is not convex as that of the other Humours, but concave, anſwering to the convex back Part of the Cryſtalline which is lodged therein, theſe Perpendiculars muſt recede from one another, as in the Figure; and conſequently the Rays, by being refracted from them, muſt be made yet more to converge, and approach one another.

By theſe Refractions, the Rays of Light which come from the Point B, are made to converge and meet again in the *Retina* at the Point *b*; and in like manner the Rays that come from all the other Points of the Object, as from A and C, are made to converge to ſo many other Points in the *Retina*, as *a*, and *c*, and by that means an inverted Picture of the Object will be painted on the *Retina*, juſt as when, by a Glaſs *Lens* placed at a Hole in the Window-ſhut of a dark Room, the inverted Images of external Objects are caſt upon a Piece of white Paper placed at a due focal Diſtance behind the *Lens*. And as this is agreeable to Reaſon and Geometry, ſo it is confirmed by Experience; for if you take off from the Bottom of an Eye, newly taken out of the Head of any Animal, a ſmall Portion of the *Tunica Choroides* and *Sclerotica*, and place this Eye in a Hole made in the Window-ſhut of a dark Chamber, ſo as the Bottom of the Eye may be towards you, you ſhall then ſee the Pictures or Images of external Objects lively painted on the *Retina*, with their proper Figures and Colours; only theſe Pictures will be inverted, as has been already noticed.

§ 5. JOHANNES BAPTISTA PORTA is the firſt I find who endeavoured to explain Viſion from Pictures entering the Eye. But as he knew nothing of the Refractions made by the Humours of the Eye, whereby theſe Pictures are rendered perfect and diſtinct, his Doctrine at beſt is but lame and defective. It is as follows:

Having diſcovered that Pictures of external Objects are made upon the Wall of a dark Room by Rays coming thro' a ſmall Hole in the oppoſite Wall, without the Interpoſition of any *Lens* to refract the Rays, (a *Phænomenon* that was then new, and had not been before obſerved by Naturaliſts), he, in his Book *de Magia Naturali*, printed in the Year 1560, deſcribes thoſe Pictures at large, and ſhews by what Methods their Diſtinctneſs may be promoted; and then concludes, that he had not only decided the grand Diſpute about the Reception and Emiſſion of Rays, which had ſo much divided the antient Philoſophers, (ſome maintaining that Viſion was cauſed by the Reception of Rays into the Eyes, whilſt others, as EUCLID, PTOLOMY, ALHAZEN, and other antient Opticians, thought it more agreeable to Nature, that certain Emanations, by them alſo called Viſual Rays, ſhould flow from an animated Subſtance to an inanimate one, rather than on the contrary); I ſay, from thoſe Pictures, PORTA concludes, that he had not only decided the grand Diſpute about the Reception and Emiſſion of Rays, but had alſo found out the true Cauſe of Viſion; for, ſays he, the Image is let in thro' the Pupil, and is painted on the Surface of the cryſtalline Humour, which anſwers to the Wall in the dark Room, as the Pupil does to the Hole in the Window-ſhutter. And here he followed the Opinion of VITELLIO and others, who imagined we began to perceive when the Cryſtalline was enlightened, but that the Perception was not compleat till it was propagated from thence and united as it were in the optic Nerve.

§ 6. In this Manner Viſion was commonly explained, till about the Year 1600, when the learned KEPLER made the grand Diſcovery, and ſhewed, by his Geometry, in what Manner the Rays were refracted thro' all the Humours of the Eye, and formed a diſtinct Picture upon the *Retina*, in like manner as Pictures are formed by a Glaſs-globe full of Water. (See his *Paralipomena ad* VITELLIONEM). He alſo diſcovered the Conſtitution of defective Eyes, that is, how the Pictures became confuſed, and ſhewed in what Manner they are rendered diſtinct by Spectacles, and concave Glaſſes, whoſe Effects had been ſo much admired from the Time of their Invention, (which was only about 300 or 320 Years before), and had ſo long perplexed the greateſt Wits to account for them. The vulgar Account of Objects appearing erect, notwithſtanding the Invertion of the Pictures upon the *Retina*, is alſo KEPLER'S, who tells us, that the Mind perceiving an Impulſe of the Ray on the lower Part of the *Retina*, conſiders this Ray as directed from a higher Part of the Object; and likewiſe perceives the Impulſe of the Ray upon the higher Part of the *Retina*, to be directed from the lower Part of the Object: Which Solution DES CARTES illuſtrates, by conceiving a blind Man to hold in his Hands two Sticks croſſing each other, and to puſh the Top and Bottom of an upright Object with their Extremities; and obſerves, that this Man will judge that to be the Upper-part of the Object, which he puſhes with the Stick held in the lower Hand; and that to be the lower Part of the Object which he touches with the Stick in his upper Hand.

§ 7. I have ſaid, that according as the Pictures upon the *Retina* are perfect or imperfect, the Objects are ſeen perfectly or imperfectly: But we are not from thence to imagine, that the Mind ſees or perceives any Pictures *in the Retina*, or that it judges of Objects from what it obſerves in theſe Pictures. This is a vulgar Error: For Proof of which I need only obſerve, That, 1*ſt*, Properly ſpeaking, there is no Picture in the *Retina*, and the Pictures which are ſeen painted there when a Bit of the *Sclerotica* and *Choroides* have been taken off from the Bottom of an Eye, are Senſations in the Mind of him who perceives them, and do not belong to the *Retina* on which they appear to be painted. Theſe Pictures, conſidered as belonging to the *Retina*, conſiſt in nothing but the Union or Coaleſcence of the Rays that come from the ſeveral Points of the Object in ſo many correſponding Points in the *Retina*; from which Points in the *Retina* they again proceed in the ſame manner as they proceeded before from the correſponding Points in the Object, and therefore affect the Eyes of the Spectator in the ſame manner, and, by affecting them in the ſame manner, produce a Senſation ſimilar to that produced by the Object itſelf. This Senſation is therefore very properly called a Picture of the Object; but this Picture being in the Mind of the Spectator, does not belong to the *Retina* on which it appears to be painted. But,

2*dly*, Tho' there was a Picture in the *Retina* in that vulgar groſs Senſe that ſo many imagine, yet it is impoſſible that the Mind could perceive it there; becauſe all the Senſations or Perceptions of the Mind are preſent with it and in the *Senſorium:* And I appeal to every one's Experience, if he ever ſees or obſerves any

Pictures or any Thing elſe in the *Retina*. And to ſay we ſee, obſerve or perceive Pictures there, without being ſenſible or conſcious of it, is abſurd and ridiculous. The Mind or ſentient Principle does not at all perceive in the *Retina*, but in the *Senſorium* where it is preſent; for when, thro' any Defect or *Paralyſis* of the Nerve, the Motions or Vibrations impreſſed on the *Retina* by the Rays forming the Picture are not propogated to the *Senſorium*, or that Place of the Brain in which the Mind reſides, the Mind perceives nothing; nor is it indeed poſſible it can perceive any thing; for whether the Mind be thought active or paſſive in its Perceptions, it is certain, that it can perceive nothing but what is preſent with it; for it can no more perceive *where it is not*, than *when it is not*; and it may as well be or exiſt *where it is not*, as act, ſuffer or perceive *where it is not*. All Things perceived muſt therefore be preſent with the Mind and in the *Senſorium*, where the Mind reſides; and that not only virtually, but ſubſtantially. *Nam virtus ſine ſubſtantia ſubſiſtere non poteſt*, as NEWTON expreſſeth it, (*Principia Mathematica, Schol. general. ſub finem.*)

It is therefore evident, that, did the Mind perceive Pictures in the *Retina*, it behoved to be there preſent: And for the ſame Reaſon, did it perceive in the other Organs of Senſe, it behoved alſo to be preſent to all the Parts of the Body; becauſe the Senſe of Feeling is diffuſed thro' all the Body: Nay, in ſome Caſes it behoved to be extended beyond the Body itſelf, as in the Caſe of Amputations, where the Perſon, after the Loſs of his Limb, has the ſame Perception of Pain, Itching, *&c.* as before, and feels them as if they were in ſome Part of his Limb, tho' it has long ago been amputated, and removed from that Place where the Mind places the Senſation. Having had this Misfortune myſelf, I can the better vouch the Truth of this Fact from my own Experience; for I ſometimes ſtill feel Pains and Itchings, as if in my Toes, Heel or Ancle, *&c.* tho' it be ſeveral Years ſince my Leg was taken off. Nay, theſe Itchings have ſometimes been ſo ſtrong and lively, that, in ſpite of all my Reaſon and Philoſophy, I could ſcarce forbear attempting to ſcratch the Part, tho' I well knew there was nothing there in the Place where I felt the Itching. And however ſtrange this may appear to ſome, it is nevertheleſs no way miraculous or extraordinary, but very agreeable to the uſual Courſe and Tenor of Nature; for, tho' all our Senſations are Paſſions or Perceptions produced in the Mind itſelf, yet the Mind never conſiders them as ſuch, but, by an irreſiſtible Law of our Nature, it is always made to refer them to ſomething external, and at a

Diſtance from the Mind; for it always conſiders them as belonging either to the Object, the Organs, or both, but never as belonging to the Mind itſelf, in which they truely are; and therefore, when the nervous Fibres in the Stump are affected in the ſame Manner as they uſed to be by Objects acting on their Extremities in the Toes, Heel or Ancle, the ſame Notice or Information muſt be carried to the Mind, and the Mind muſt have the ſame Senſation, and form the ſame Judgment concerning it, *viz.* that it is at a Diſtance from it, as if in the Toes, Heel or Ancle, tho' theſe have long ago been taken off and removed from that Place where the Mind places the Senſation.

If this ſhould prove hard to be conceived, it may be illuſtrated by what happens in the Senſation of Colours; for tho' the Colours we perceive are preſent with the Mind, and in the *Senſorium*, yet we judge them at a Diſtance from us, and in the Objects we look at; and it is not more difficult to conceive how Pain may be felt at a Diſtance from us, than how Colours are ſeen at a Diſtance from us.

§ 8. This may ſtill be further illuſtrated, by conſidering Viſion by Reflection or Refraction; for an Object ſeen by Reflection or Refraction does not appear in its true Place, but in that Place from whence the Rays after their laſt

Reflection or Refraction diverge, in falling on the Spectator's Eye. Thus, if the Object A (PLATE III. *Fig.* 24.) be ſeen by Reflection of a Looking-glaſs *mn*, it ſhall appear not in its proper Place A, but behind the Glaſs at *a*, from whence any Rays AB, AC, AD, which flow from one and the ſame Point of the Object, do, after their Reflection made in the Points B, C, D, diverge in going from the Glaſs to E,F,G, where they are incident on the Spectator's Eyes. In like manner, the Object D (*Fig.* 25.) ſeen thro' a *Priſm*, appears not in its proper Place D, but is thence tranſlated to ſome other Place *d*, ſituated in the laſt refracted Ray FG, drawn backwards from F to *d*. And ſo the Object Q (*Fig.* 26.) ſeen thro' the *Lens* AB, appears at the Place *q*, from whence the Rays diverge in paſſing from the *Lens* to the Eye.

Now, as Objects ſeen by Reflection or Refraction appear and are ſeen, not in their true Place, but in ſome other Place from which they are abſent, and that becauſe the Rays fall upon the Eyes, and make a Picture on their Bottom, in the very ſame Manner as if they had come from the Object really placed there, without the Interpoſition of the Glaſs; ſo, when the Impreſſion made upon the nervous Fibres of the Stump is the ſame as if it had come from an Object acting on their Extremities,

ties, the Senſation muſt alſo be the ſame, and the Mind, by forming the ſame Judgment concerning it, muſt feel it as in the Toes, Heel or Ancle, *&c.* in which thoſe nervous Fibres terminated before the Leg was taken off.

§ 9. The ingenious Dr. WHYTT, in order to account for the Motions of the Heart, and the other Muſcles of Animals after Death, or their Separation from the Body, has ſuppoſed, that the Soul is preſent with every Part of the Body, not only when the Body is intire, but even after it is divided, and its Parts removed from one another, perhaps to the Diſtance of many Miles; and has alſo ſuppoſed, that, in different Parts of the Body, it exerciſes different Faculties; that it can only exerciſe the Power of reflex Conſciouſneſs, Imagination, Judgment, Reaſon and Memory in the Brain; can only taſte in the Tongue, ſmell in the Noſe, ſee in the Eyes, hear in the Ears, and feel Hunger in the Stomach, and Pain over all the Body. (See WHYTT's *Eſſay on the Vital Motions*, Sect. xiii. and *Phyſiological Eſſays*, Eſſ. II. Sect. 2.)

But to me ſuch Suppoſitions ſeem much more unaccountable than the *Phænomena* themſelves they are brought to explain; for if the Soul continues preſent with every Part of the

Body after they are removed to a great Diſtance from one another, the Soul itſelf muſt neceſſarily be diſcerpible: and it is no Anſwer to this, to ſay, "That the Soul is a Subſtance "ſo perfectly and eſſentially one, that any "Diviſion or Separation of its Parts do "neceſſarily infer a Deſtruction of its "Eſſence." This indeed will readily be acknowledged; but it will not from thence follow, that this ſame indiviſible Soul, which is ſuppoſed to co-exiſt with all the different Parts of the Body, can continue to co-exiſt with them after they are ſeparated, and yet ſtill continue one, without any Diviſion or Separation. The natural and plain Conſequence of this Indiviſibility of the Soul is, that it cannot continue preſent with all the Parts of the Body after they are ſeparated, and conſequently this Hypotheſis ought to be laid aſide, as repugnant to that Oneneſs and Indiſcerpibility of the Soul, of which we have ſo many irrefragable Proofs.

To ſay, that the Soul continues preſent with all the Parts of the Body after their Separation, and yet is not itſelf ſeparated or divided is to ſay, either that the Soul can wholly exiſt in the Parts of the Body, and yet at the ſame Time alſo exiſt in the intermediate Space; which is a plain aud direct Contradiction, as no Subſtance can exiſt in two or more different Places at the ſame Time: Or if this is not ſaid, we muſt at leaſt ſay, that the Soul does not wholly exiſt in the Parts, as it did before their Separation, but partly in the Parts, and partly in the intermediate Space, "ſo as to "have its Sphere of Exiſtence increaſed;" which ſeems to be the Opinion of this learned Author. But this alſo neceſſarily infers Separation, and of conſequence Diviſibility; for if the Parts of the Soul can be removed from one another, they can alſo be ſeparated and divided from one another. And as this Reaſoning does not depend "on the Nature of "the Soul, or the Manner of its Exiſtence, or "on the way in which it acts upon or is pre-"ſent with the Body," our being "ignorant "of theſe," is nothing to the purpoſe: All that this Reaſoning ſuppoſes, is, that the Soul is one indiviſible Subſtance, and that it is ſubſtantially preſent, where it is allowed to be ſubſtantially preſent: and therefore it is preſumed this Reaſoning will be eſteemed of ſome Force, tho' we knew leſs of the Nature, Powers and Properties of the Soul, than we really do.

And with reſpect to the Soul's exerciſing different Faculties in different Parts of the Body, this alſo ſeems to me to be extremely unphiloſophical; for the whole Soul is but one, and this one whole Soul has not ſome Powers here, and other Powers there, but all its Powers are the Powers of the whole, and all its Actions are the Actions of the whole; and this one whole Soul exerciſes all its Powers and Faculties in that whole Place in which it is.

But, that I may not tire the Reader with metaphyſical Reaſoning, I ſhall content myſelf with a Quotation from the learned Dr. CLERK. His Words are: " The Organs of " the Senſes are intirely diſtinct from one an" other, but the Thing that perceives by " thoſe different Organs is one and the ſame " Thing, one thinking Being, which every " Man calls himſelf; and this one thinking " Being has not ſome Powers in ſome Parts, " and other Powers in other Parts, ſome " Actions in ſome Parts, and other Actions " in other Parts; but all its Powers are the " Powers of the whole, and all its Actions are " the Actions of the whole; the whole think" ing Subſtance ſees both the whole Object " and every Part of it; the ſame whole think" ing Subſtance hears every Sound, ſmells " every Odour, taſtes every Sapor, and feels " every Thing that touches any Part of the " Body. Every Imagination, every Volition, " and every Thought, is the Imagination, Will " and Thought of the whole thinking Sub" ſtance, which I call *Myſelf*; and if this one

"Subſtance (which we ſtile the Soul of Man) "has not Parts which can act ſeparately, it "may as well be conceived to have none "that can exiſt ſeparately, and ſo be abſolutely "indiviſible." (See CLERK's 3*d*. *Defence of his Letter to* Mr. DODWELL.) But it would ſeem, that Dr WHYTT has overlooked this Paſſage, elſe it is to be preſumed he would have made ſome Anſwer to it, and to the Arguments ſcattered up and down theſe Defences in ſupport of it; eſpecially that Dr. CLERK is allowed to be a Man of great Authority, and that Dr. WHYTT himſelf, in quoting theſe very Defences, has told us, "that Perſpicuity, Metaphyſics, and ſound "Philoſophy, are happily united in them." (*Eſſ. on the Vital Motions, p.* 281.) But to return.

§ 10. Having ſhewed, that the Mind does not ſee any Pictures in the *Retina*, or judge of Objects from what it obſerves in theſe Pictures, it will be aſked, what Connection there then is betwixt Viſion and theſe Pictures, and how it comes to paſs, that Objects are ſeen perfectly or imperfectly, accordingly as theſe Pictures are perfect or imperfect.

To this I anſwer, That tho' all our Perceptions are Modifications of the Mind itſelf ariſing from the Motions or Vibrations excited in the *Senſorium*, to which the Mind is preſent; yet the Mind never conſiders them as ſuch, but always aſcribes them, either to the Object, the Organs, or both. This I have already hinted at, and ſhall have Occaſion afterwards to demonſtrate more particularly, that, in ſeeing Objects, the Mind, by means of an original and connate Law, to which it has always been ſubjected, traces back its own Preceptions, not only from the *Senſorium* to the *Retina*, but from thence alſo outwards towards the Object itſelf, along right Lines drawn perpendicularly to the *Retina* from every Point of it on which any Impreſſion is made by the Rays forming the Picture; by which means the Mind or viſive Faculty does always ſee every Point of the Object, not in the *Senſorium* or *Retina*, but without the Eye, in theſe perpendicular Lines. And this being ſo, it is eaſy to underſtand how the Object appears perfect, or imperfect, according as its Image on the *Retina* is perfect or imperfect, without having Recourſe to the groundleſs Suppoſition of the Mind's ſeeing a Picture in the *Retina*; for when the Rays that come from the ſeveral Points of the Object are not exactly united upon the *Retina*, the Picture of each Point will be a Spot that takes up a conſiderable Space upon the *Retina*, and which, by being mixed and confounded with the Pictures of the neighbouring Points, which alſo are Spots, muſt make all the Points of the Object to be ſeen in a great many Places, and a great many of theſe Points to be ſeen in the ſame Place; from which Confuſion, the Appearance of the Object will alſo be confuſed and indiſtinct.

To illuſtrate this, let COB (Plate IV. *Fig.* 27.) be an Object, whoſe Points O, B and C, by emitting Rays that are not re-united at the *Retina*, but beyond it as far as X, do, upon the *Retina*, form the circular Images *o*, *b* and *c*; and let F be the Centre of the Eye, thro' which every Line that is drawn perpendicular to the *Retina* muſt paſs. From the extreme Points of theſe circular Images on the *Retina* *o*, *b* and *c*, draw right Lines to the Centre F, and continue them to the *Horopter*, as in the Figure; theſe Lines, by reaſon they paſs thro' the Centre of the Eye F, will be perpendicular to the *Retina*: Whence it is evident, that the Points O, B and C muſt be ſeen without the Eye in the whole of the circular Spaces OCIB, BOLH, and CGKO, which are comprehended within the right Lines drawn perpendicularly to the *Retina* from the extreme Points of the Images of the reſpective Points; which Circles being mixed and confounded with one another, it follows, that the Points O, B and C muſt, for the Reaſon above obſerved, appear confuſed and indiſtinct,

diſtinct, tho' the Eye ſees not the Confuſion that is in their Images on the *Retina.*

§ 11. Before I diſmiſs this Subject, it may be proper to notice, by way of Corollary; that, ſince diſtinct Viſion depends on the Diſtinctneſs of the Pictures, on the *Retina*, it is impoſſible our Sight can ever be abſolutely diſtinct and perfect; becauſe theſe Pictures, even in the beſt Eyes, are always ſomewhat confuſed and indiſtinct. This Confuſion in the Pictures ariſes from a twofold Cauſe; *Firſt*, the Sphericalneſs of the Figures of the refracting Humours; and, *Secondly*, the different Refrangibility of the Rays.

§ 12. As to the *Firſt*, it is a Thing well known, that, after the Diſcovery of the true Law of Refraction, according to the given *Ratio* of the Sines, DES CARTES, and other Mathematicians, ſoon found, that all the Rays of a large Pencil could not poſſibly be collected to a diſtinct Point by any *Lens* compoſed of ſpherical Surfaces, having every where the ſame Degree of Curvity; and that the Aberrations of the Rays from that Point, were increaſed with the Breadth of the Glaſs; the exterior Rays of the Pencil being gradually too much bent, as they receded from the *Axis* of the *Lens*; or, which is the ſame Thing, the interior Rays being gradually too little bent, as they approached this ſame *Axis*, to belong all together to one ſingle Point after Refraction; and conſequently the Angles of Incidence of the exterior Rays are too large for that Purpoſe, both at the firſt and ſecond Surface of the Globe or *Lens*. Theſe Aberrations, cauſed by the ſpherical Surfaces of Glaſſes, were then thought the only Impediment to the Perfection of Teleſcopes; and this engaged the Mathematicians in determining what Figure a Glaſs muſt have to refract all the Rays of a Pencil to a given Point; and having found, that Glaſſes figured according to the Surfaces deſcribed by Conic Sections turned about their *Axes*, would have that Effect, they preſently fell a contriving Engines for grinding and poliſhing Glaſſes according to the Shape of theſe Conic Surfaces. Sir ISAAC NEWTON himſelf was employed in this Work in the Year 1666; but having a Curioſity at the ſame time to try the celebrated *Phænomena* of the Colours generated by the Refraction of a Priſm, by which he happily diſcovered their Cauſes, he preſently left off his Glaſs-works; for he ſaw, that the Perfection of Teleſcopes was limited, not ſo much for want of Glaſſes properly figured, as becauſe Light itſelf is a heterogeneous Mixture of differently refrangible Rays; ſo that, were a Glaſs ſo exactly figured as to collect any one Sort of Rays into a Point, it would not collect theſe alſo into the ſame

Point, which, having the ſame Incidence upon the ſame *Medium*, are diſpoſed to ſuffer a greater Degree of Refraction. This made NEWTON take Reflections into Conſideration; and finding them always regular, ſo that the Angle of Reflection of all Sorts of Rays was equal to their Angle of Incidence, he ſoon underſtood, that, by their Mediation, optic Inſtruments might be brought to the greateſt Perfection. And not long after that, he perfected ſuch an Inſtrument 6 inches long, which magnified 30 or 40 Times, which he firſt deſcribed in the *Philoſophical Tranſactions*, and afterwards in his *Optics*. and this is indiſputably the greateſt Improvement that Teleſcopes have ever received ſince their firſt Invention; tho' it muſt be acknowledged, that Mr. JAMES GREGORY of *Aberdeen* was the firſt Inventer of a reflecting Teleſcope, which he was led to, not by the Conſideration of the different Refrangibility of the Rays, which was not then known, but from an Inconvience he ſaw would follow from an hyperbolic Object-glaſs. Mr. GREGORY deſcribes this Teleſcope at the End of his *Optica Promota*, publiſhed *ann.* 1663; but its Conſtruction is quite different from Sir ISAAC NEWTON's, and not near ſo advantageous, as Sir ISAAC himſelf has ſhewn. But to return:

§ 13. Tho', ſtrictly ſpeaking, there is always ſome Confuſion in our Sight, ariſing from the Spericalneſs of the Surfaces of the refracting Humours; yet this Confuſion is ſo very ſmall, that we are not ſenſible of it. The Reaſon of which may be gathered from a *Theorem* I find in NEWTON's *Optics* for determining the Degree of Confuſion ariſing from the ſpherical Figure of the Glaſs in Pictures formed by a *Plano-convex Lens*. The *Theorem* is as follows:

If the Object-glaſs of a Teleſcope be plano-convex, and the plain Side be turned towards the Object, and the Diameter of the Sphere whereof this Glaſs is a Segment, be called D, and the Semidiameter of the Aperture of Glaſs be called S, and the Sine of Incidence out of the Glaſs into Air be to the Sine of Refraction as I to R, the Rays which flow from a lucid Point ſo very remote from the *Lens*, that, before their Incidence, they may be accounted parallel, ſhall, in the Place where the Image is moſt diſtinctly made, be ſcattered all over a little Circle, whoſe Diameter is $\frac{R^2}{I^2} \times \frac{S^3}{D^2}$ very nearly. As, for Inſtance, if the Sine of Incidence I, be to to the Sine of Refraction R, as 20 to 31, and if D, the Diameter of the Sphere to which the convex Side of the Glaſs is ground, be 100 Feet or 1200 Inches, and S, the Semidiameter of the Aperture, be 2 Inches; the Diameter of the little Circle (that is, $\frac{R^2 \times S^3}{I^2 \times D^2}$ will be $\frac{31 \times 31 \times 8}{20 \times 20 \times 1200 \times 1200}$ or $\frac{961}{72000000}$ Parts of an Inch.

§ 14. From this *Theorem*, it is eaſy to ſee, that the Circle of Aberrations from the *Focus*, ariſing from the ſpherical Figure of refracting *Mediums*, is ſo very ſmall, that it can occaſion no ſenſible Confuſion in the Pictures on the *Retina*, and conſequently cannot occaſion any ſenſible Indiſtinctneſs in the Appearance of Objects; eſpecially if it is conſidered that the middle-moſt Rays of a Pencil are crowded ſo cloſe together by Refraction at ſpherical Surfaces and *Lenſes*, and the outermoſt Rays are ſcattered ſo thin upon a Plane, paſſing thro' the *Focus* perpendicular to the *Axis*, that the Confuſion they make in a Picture, by mixing with the Rays of other Pencils, muſt be next to nothing, when the Pupil is of a moderate Size.

§ 15. But the Confuſion ariſing from the other Cauſe, the different Refrangibility of the Rays, is many hundred times greater. For underſtanding this, let AB (PLATE IV. *Fig.* 28.) be a *Lens*; EA, CI, FB, parallel Rays; and let R be the *Focus* into which the leaſt refrangible or Red-making Rays are collected; the *Focus* V, into which the moſt refrangible or Violet-making Rays are collected, ſhall be nearer to the *Lens* than the *Focus* R of the leaſt refrangible Rays, by about the 28th Part of the whole Diſtance RI; as NEWTON has demonſtrated from accurate Experiments. If therefore thro' R and V the Lines KL and MN be drawn perpendicular to the *Axis* CIR; MN ſhall be $\frac{1}{28}$ Part of the Breadth of the Glaſs AB, and KL $\frac{1}{27}$ Part: Whence OP, the Diameter of the Circle in the middle Space between theſe two *Foci*, (which Circle is the leaſt into which all the Rays can be gathered) is about the 55th Part of the Diameter of the Glaſs, or of its Aperture, if it have one. And therefore the Error ariſing from the different Refrangibility of the Rays in ſuch a *Lens*, as was mentioned in the above *Theorem*, where the Aperture was 4 inches, will be meaſured by a Circle whoſe Diameter is $\frac{4}{55}$ Parts of an Inch; whereas the Error ariſing from the Sphericalneſs of the refracting Surface, was found to be only $\frac{961}{72000000}$ parts of an Inch, which is 5449 times leſs than the Error ariſing from the different Refrangibility of the Rays; and therefore being in Compariſon ſo very little deſerves not to be conſidered.

§ 16. But you will ſay, if the Errors cauſed by the different Refrangibility be ſo very great, how comes it to paſs that Objects appear ſo diſtinct as they do, both thro' Teleſcopes, and to the naked Eye.

To this I anſwer, in the Words of NEWTON, It is becauſe the erring Rays are not ſcattered uniformly over all that circular Space, but collected infinitely more denſely in the Centre, than in any other Part of the Circle; and in the Way from the Centre to the Circumference, grow continually rarer and rarer, ſo as at the Circumference to become infinitely rare, and, by Reaſon of their Rarity, are not ſtrong enough to be viſible, unleſs in the Centre, and very near it.

For illuſtrating this, Sir ISAAC has given us a *Theorem* in his *Optics* which deſerves to be noticed here. It is as follows:

Let ADE (PLATE IV. *Fig.* 29.) repreſent one of thoſe Circles deſcribed with the Centre C, and Semidiameter AC; and let BFG be a ſmaller Circle concentric to the former, cutting with its Circumference the Semidiameter AC in B; and biſect AC in N; by Computation, Sir ISAAC found, that the Denſity of the Light in any Place B, is to its Denſity in N, as AB is to BC; and that the whole Light within the leſſer Circle BFG, is to the whole Light within the greater AED, as $AC^2 - AB^2$ is to AC^2. Thus, if BC be the 5th Part of AC, the Light will be four times denſer in B than in N, and the whole

Light within the leſſer Circle, will be to the whole Light within the greater as 9 to 25. Whence it is evident, that the Light within the leſs Circle muſt ſtrike the Senſe much more ſtrongly than that faint and dilated Light round about between it and the Circumference of the greater.

But it is further to be noted, that the moſt luminous of the priſmatic Colours are the Yellow and Orange. Theſe affect the Senſes more ſtrongly than all the reſt together, and next to theſe in Strength are the Red and Green. The Blue compared with theſe is a faint and dark Colour; and the Indigo and Violet are much darker and fainter; ſo that theſe, compared with the ſtronger Colours, are little to be regarded. The Images of Objects are therefore to be placed, not in the *Focus* of the mean refrangible Rays, which are in the Confine of Green and Blue, but in the *Focus* of thoſe Rays which are in the Middle of the Orange and Yellow; there where the Colour is moſt luminous and fulgent, that is, in the brighteſt Yellow, that Yellow, which inclines more to Orange than to Green. And by the Refraction of theſe Rays (whoſe Sines of Incidence and Refraction in Glaſs are as 17 and 11), the Refraction of Glaſs and Cryſtal for optical Uſes is to be meaſured. Let us therefore place the Image of the Object in the *Focus* of theſe Rays, and all the Yellow and Orange will fall within a Circle, whoſe Diameter is about the 250th Part of the Diameter of the Aperture of the Glaſs *Lens:* And if you add the brighter Half of the Red (that Half which is next the Orange), and the brighter Half of the Green (that Half which is next the Yellow) about $\frac{3}{5}$ Parts of the Light of theſe two Colours will fall within the ſame Circle, and $\frac{2}{5}$ Parts will fall without it round about; and that which falls without will be ſpread thro' almoſt as much more Space as that which falls within, and ſo in the groſs be almoſt 3 times rarer. Of the other Half of the Red and Green (that is of the deep dark Red and willow Green) about one Quarter will fall within this Circle and three Quarters without; and that which falls without will be ſpread thro' about 4 or 5 times more Space than that which falls within; and ſo in the groſs be rarer, and, if compared with the whole Light within it, will be about 25 times rarer than all that taken in the groſs; or rather more than 30 or 40 times rarer, becauſe the deep Red in the End of the *Spectrum* of Colours made by a *Priſm* is very thin and rare, and the willow Green is ſomething rarer than the Orange and Yellow. The Light of theſe Colours therefore being ſo very much rarer than that within the

Circle, will ſcarce affect the Senſe, eſpecially ſince the deep Red and willow Green of this Light are much darker Colours than the reſt. And, for the ſame Reaſon, the Blue and Violet being much darker Colours than theſe, and much more rarified, may be neglected. For the denſe and bright Light of the Circle, will obſcure the rare and weak Light of theſe dark Colours round about it, and render them almoſt inſenſible. The ſenſible Image of a lucid Point is therefore ſcarce broader than a Circle whoſe Diameter is the 250th Part of the Diameter of the Aperture of the Object-glaſs of a Teleſcope by which the Image is made, or not much broader, if you except a faint and dark miſty Light round about it, which a Spectator will ſcarce regard. And therefore, in a Teleſcope whoſe Aperture is four Inches, and Length one hundred Feet, it exceeds not 2″ 45‴, or 3″. And in a Teleſcope whoſe Aperture is two Inches, and Length 20 or 30 Feet, it may be 5″ or 6″, and ſcarce above. And this anſwers well to Experience; for in ſuch Teleſcopes the fixed Stars, which, by reaſon of their immenſe Diſtance, appear like Points, unleſs ſo far as their Light is dilated by Refraction, and which therefore, when eclipſed by the Moon, vaniſh not gradually, like the Planets, but all at once, and in the End of the Eclipſe return again into Sight all at once; I ſay, in ſuch Teleſcopes the fixed Stars appear to be about $5''$, $6''$ or $7''$ in Diameter, or not much above, as Aſtronomers have found, by taking the Diameter of their Image formed at the *Focus* of the Object-glaſs by means of a *Micrometer*; for theſe Images ſubtend at the Centre of the Object-glaſs an Angle of about $5''$, $6''$ or $7''$, and ſcarce more. But if the Eye-glaſs be tinged faintly with the Smoke of a Lamp or Torch, to obſcure the Light of the Star, the fainter Light in the Circumference of the Star ceaſes to be viſible, and the Star (if the Glaſs be ſufficiently ſoiled with Smoke) appears ſomething more like a mathematical Point.

§ 17. But to apply this Doctrine more particularly to the Eye, it muſt be remembered, that the optic Nerve is a Bundle of very ſmall Fibres or Threads of a certain determinate Bigneſs: Theſe Fibres at one End ariſe from the Brain, and at the other terminate in the *Retina*; upon the anterior Surface of which they may be ſuppoſed to ſtand erect, like the Pile on Velvet: Whence it comes to paſs, that when an Object is ſo ſmall, or ſo far removed from the Eye, as to form a Picture on the *Retina* leſs than one ſingle Fibre, that Object will not be ſeen, becauſe of the Weakneſs of the Impreſſion, unleſs it be very bright and luminous; in which caſe the whole Fibre will be moved by having one Part of it powerfully acted on; and therefore the Senſation will be the ſame, as if the Object were much bigger, and did take up or cover the whole End of the Filament, tho' it affects but a tenth Part of it: For, as there can be no more diſtinct Senſations, than there are diſtinct Threads to convey the Impreſſion on them, ſo, when the Fibre is moved, whether by an Impreſſion made on the whole, or on a ſmall Part of it, the Senſation will always be the ſame, and the Magnitude of the Object, however ſmall it may be, will be eſtimated, not by the Magnitude of the Picture, but by the Magnitude of the nervous Fibre, on a Part of which the Picture is only made. And as this is agreeable to Reaſon, ſo it is alſo confirmed by Experience; for the learned Dr. HOOK, and other Naturaliſts, found by Experiments which they made on Purpoſe for examining this Theory, that there is a *Minimum Viſibile*; that this in moſt Eyes is comprehended within an Angle of one Minute; and that whatever is ſeen, is ſeen of that Bigneſs, or under that Angle. The Dr. indeed owns, that there are ſome who can ſee to the third of a Minute, but aſſures us, that theſe are very few. (See *his Poſthumous Work*, *p.* 12. and 97.). And this is the Reaſon why every

Star that the Eye diſcovers appears to moſt Men to be of the Bigneſs of a Minute at leaſt; and ſo it is conceived really to be, tho' yet, when we come to examine its Diameter by the help of a Teleſcope, we find it to be but ſome few Seconds or 60th Parts of ſuch an Angle.

Now, this much being premiſed concerning the *Minimum Viſibile,* it will not be difficult to ſhew, how far our Sight is affected by the different Refrangibility of the Rays.

For underſtanding this, let AB, AE and BD (PLATE IV. *Fig.* 30.) be each of them Diameters of a *Minimum Viſibile* ſubtending an Angle at C, where the Pencils cut one another within the Eye of Half a Minute or 30 Seconds; theſe circular *Minima* ſhall on the *Retina* form circular Pictures whoſe Diameters *ab*, *ae* and *bd*, will alſo ſubtend an Angle at C of Half a Minute or 30 Seconds, and will take up or cover the whole Ends of the nervous Fibres P, Q and R, on which they fall.

By this Means each of theſe *Minima* will be ſeen diſtinctly and ſeparately, without any Mixture or Confuſion; for as each of them makes its Picture on one ſingle Fibre, the Motion thereby excited in the Fibre muſt produce one uniform Senſation throughout the the whole Extent of the *Minimum Viſibile:*

So that all the Parts of the *Minimum Viſibile* muſt appear ſimilar and alike, without any Diverſity in its Parts: And this is the Reaſon why, when one Part of the *Minimum Viſibile* is yellow, and the other Part blue, as in a Mixture of blue and yellow Powders, the whole appears green: For the ſame nervous Fibre, receiving one Kind of Motion from the yellow Colour, and another from the Blue, will, from both together, get a Motion different from, but compounded of both; to which Motion the Senſation of Green being connected by a Law of our Nature, the whole *Minimum Viſibile* muſt appear Green: And the like Way of Reaſoning will account for its other Appearances, when its Parts are of other Colours, or otherwiſe differently diſpoſed.

Thus it would be, were the Rays all equally refrangible: Let us now ſee what will follow from a different Refrangibility of the Rays.

For this Purpoſe, let the Circle of Aberrations from the *Focus*, ariſing from the different Refrangibility of the Rays, be ſuppoſed to be 6 Seconds in Diameter; it is obvious, that the Rays AC and BC, which may be conceived to belong not only to the *Minima* AE and BD, but alſo to the *Minimum* AB lying betwixt them; I ſay, it is obvious, that theſe Rays will on the *Retina* form the Circles *a* and *b*, whoſe Diameters will at C ſubtend an Angle of 6 Seconds: In like manner, if from the outward Limits of theſe Circles *a* and *b* the right Lines *c*CF, *f*CG be drawn, all the Points lying betwixt A and F, and betwixt B and G, will form ſuch little Circles on the *Retina;* a Part of all which Circles will fall on the Picture *ab*, and the *Annulus* at the Edge of this circular Picture on which theſe erring Rays fall, will be in Breadth 3 Seconds or the 10th Part of the Diameter of the Picture; whence the Area of the *Annulus* will be to the whole Area of the Picture, as 324 to 900; which is a Proportion ſomewhat greater than that of 1 to 3; and therefore the *Minimum Viſibile* AB will not appear abſolutely diſtinct, or as it is, by reaſon of the enormous Rays belonging to the *Minima Viſibilia* round about it; which being mixed in its Picture on the *Retina* throughout the whole of this *Annulus*, muſt make the *Minimum* partake of the Appearance of the *Minima* round it, as theſe partake of the Appearance of the *Minima* round them, and theſe again of others round them, and ſo on; ſo that the Senſation of every *Minimum* will be affected by the whole *Minima* which are contiguous to it, and conſequently none of thoſe *Minima* will appear altogether diſtinct, or as they are. But, as I like not to dwell too long on ſuch Subtilities, leaving this Subject to be further purſued by others, who may be more as leiſure and are more ſkilled in Mathematics than I am, I ſhall proceed.

CHAP. III.

*Of the Change that is made in the Eye in order to ſee diſtinctly at different Diſtances, and of the Uſe of the Ciliary Ligament in producing this Change**.

SECT. I. FROM what has been ſaid in the preceeding Chapter concerning the Manner of Viſion, and the Uſe of the ſeveral Humours of the Eye in refracting the Rays, ſo as to make the Pictures of Objects diſtinct, it follows, that, in order to ſee Objects at different Diſtances diſtinctly, it is neceſſary that there ſhould be a Change in the Eye, leſt the Place in which the Picture of the Object is exact ſhould fall ſhort of or beyond the *Retina*, and ſo cauſe the Viſion to be confuſed: For Inſtance, if juſt now my Eye is of ſuch a Conformation, as that, when I look upon an Object at a Foot Diſtance, I ſee it perfectly and diſtinctly, by reaſon that the Rays, which, in coming from the ſeveral Points of the Object, fall upon my Eye, are ſo refracted by the Humours thereof, as to converge and meet again in ſo many diſtinct Points at the *Retina*; if this ſame Object be removed to five or ſix Feet Diſtance, and the Eye, at the ſame time, retain unalterably its former Conformation, it muſt appear confuſed and indiſtinct; becauſe the Rays, which come from the Object at this Diſtance, are leſs diverging, than when it was at a Foot Diſtance; and conſequently will, in paſſing the Humours of the Eye, be made to conveen before they reach the *Retina*, and ſo paint thereon a confuſed Image of the Object: Whence it ſeems evident, that, in order to ſee Objects equally diſtinct, at one Foot's Diſtance, and ſix Feet Diſtance, it is neceſſary that the Eye change its Conformation; either, by having its Humours made more or leſs flat, or, having the Diſtance betwixt the *Cryſtalline* and the *Retina* increaſed or diminiſhed. And this does likewiſe further appear by the Analogy of the Images painted on the *Retina*, and thoſe painted on a Sheet of white Paper, by means of a *Lens* placed at a Hole in the Window-ſhut of a dark Chamber; for if the *Lens* be of ſuch a Convexity, as is neceſſary to paint the Image of a Body, at a Foot Diſtance from it, diſtinctly upon a Sheet of white Paper, five or ſix Inches behind the *Lens*, the ſame Object removed to the Diſtance of ſix Feet from the Window, will not be painted exactly upon the Paper, unleſs, in place of the former *Lens*, you ſubſtitute one leſs convex, or diminiſh the Diſtance betwixt the *Lens* and Paper, by bringing the Paper nearer the Window.

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* What follows on this Head, is moſtly taken from what I publiſhed before in the *Edinburgh Medical Eſſays, Vol.* IV. which having been well received by the Public, I thought it beſt to make but few Alterations in it, excepting ſuch as were abſolutely neceſſary for connecting it with the preſent Treatiſe.

§ 2. From theſe and ſuch like Arguments, taken from the Manner of Viſion, moſt Phyſicians, as well as Philoſophers, have been brought to believe, that we have a Faculty of changing the Conformation of our Eyes, in order to ſee Objects diſtinctly at different Diſtances; yet the famous *French* Academiſt *Mr. de la* HIRE is of a contrary Opinion, and contends, that at whatever Diſtance Objects be placed, yet the Eyes never alter their Conformation; and this he endeavours to demonſtrate from ſeveral Reaſons, and particularly from the following Experiment, which is truly very ingenious and beautiful:

Take a Card, and pierce it with a Pin in two, three or more Places, ſo as the moſt diſtant Holes be not further from one another than the Wideneſs of the Pupil: This done, ſhut one of your Eyes, and apply the Card cloſe to the other, ſo as to view a ſmall Object through its Holes; you ſhall be ſurprized to ſee this Object multiplied as many times as there are Holes in the Card, providing it be placed out of that preciſe Place, where it would be moſt diſtinctly ſeen by the naked Eye; *e.g.* If I ſee an Object diſtinctly when at a Foot Diſtance, it will appear ſingle at that Diſtance, when viewed thro' the perforated Card; but if it be removed to four, five or ſix Feet Diſtance, it will always appear multiplied as often as there are Holes in the Card. In like manner, if the Conformation of the Eye be ſuch, as it cannot ſee Objects diſtinctly but a t four Feet Diſtance, it will at that Diſtance appear ſingle through the Card, but at all leſſer Diſtances it will be multiplied.

To make This Experiment with Exactneſs, you muſt, for an Object, look to a ſmall luminous Point in a dark Place, ſuch as a little Hole in a Card placed before a Candle, or elſe you muſt look at a ſmall black Object placed before a white Surface.

Now, it is certain, that if the Rays of Light that come from each Point of the Object are exactly united in a correſponding Point of the *Retina*, the Object will always appear ſingle, tho' it be viewed thro' ſeveral ſmall Holes; for the little luminous Cones, OHH, O*hh*, (PLATE IV. *Fig.* 31.) which have for their *Apex* or Top a Point of the Object O, and for their *Baſis* the little Holes in the Card HH, *hh*, will alſo have all their oppoſite Tops *oo*, in one and the ſame Point *o* of the *Retina* RR, which muſt needs make the Object appear ſingle: But if the Eye have not that Conformation, which is neceſſary to re-unite theſe Rays in a Point in the *Retina*, each of theſe little Cones will be cut by the *Retina*, either before or after their Re-union, and therefore each Point of the Object ſhall, by its Rays, touch the *Retina* in as many diſtinct Places as there are Holes in the Card; and conſequently the Object will appear multiplied, according to the Number of Holes. Thus, if the Rays conveen before the *Retina*, let AB be the *Retina*, it is evident, from the Figure, that this muſt receive the luminous Pencils at two diſtinct Places *x* and *x*. And if the Rays conveen behind the *Retina*, let CD be the *Retina*, which alſo muſt receive the luminous Cones at the diſtinct Places *c* and *c*. In both which Caſes, the Object muſt appear double, by reaſon that its Picture falls on two diſtinct Places of the *Retina*: Whence it is eaſy to ſee, that if the

Card be pierced in three or more Holes, ſo as the moſt diſtant Holes may not be further from one another than the Diameter of the Pupil; the luminous Pencils, and the Places in the *Retina* where theſe Pencils do fall, muſt be multiplied according to the Number of Holes; from which Multiplication the Object itſelf muſt alſo be equally multiplied. From all which, the above named Author concludes, that the Conformation of our Eyes is never changed, at whatever Diſtance Objects be placed: For, ſuppoſe that I ſee an Object diſtinctly at a Foot Diſtance, and at the ſame Diſtance it appears ſingle, when viewed through the perforated Card; if, to ſee the ſame Object at four Feet Diſtance, it were requiſite that the Eye changed its Conformation, then he concludes it would do ſo, when the Object is viewed at that Diſtance through the Card; which does not happen, as is evident from its being multiplied.

This is the great Argument whereby *M. de la* Hire, both in the *Journal des Sçavans, ann.* 1685, and in his Diſſertation *ſur les differens Accidens de la Vüe* publiſhed in the Year 1693, endeavours to prove, that the Cryſtalline does not change its Figure or Situation, and in general, that the Eye receives no new Figure or Conformation, in viewing Objects at different Diſtances. And, to do Juſtice to the learned

Author, it muſt indeed be acknowledged, that at firſt View the Argument ſeems to go a great Way towards a full Demonſtration of what he alledges; nor, ſo far as I know, has any Thing been yet offered by any Author, whether Phyſician, Anatomiſt or Optician, that can in the leaſt weaken or diſprove it; and yet all of them, excepting MAITRE-JEAN and ſome few others, continue to teach, that our Eyes change their Conformation according to the Diſtance of Objects, without ſo much as once taking notice of *de la* HIRE's Reaſoning, or attempting at an Anſwer; which muſt appear very ſtrange to every Body that conſiders the Character of the Author, the Strength of his Reaſoning, and how long ago it is that his Opinion has been publiſhed to the World.

§ 3. In anſwer to this Argument of *de la* HIRE, I once ſuſpected, that, when an Object is viewed thro' a preforated Card, the Eye, by endeavouring to ſee the Card, adapted itſelf to as near a Diſtance as it could, and, by continuing in that State, occaſioned the Object to appear multiplied when at a greater or leſſer Diſtance, than that to which the Eye is then accommodated; but, by ſome Experiments, to be mentioned below, it ſoon appeared, that the Eye did not endeavour to ſee the Card, nor by any ſuch Endeavour was it accommodated to the neareſt Diſtance poſſible; and therefore ſomething elſe muſt be ſought for, in order to reconcile this Multiplication of the Object with our having a Power of accommodating our Eyes to its Diſtance.

But, for the better underſtanding this Matter, it may be proper, before I go further, to clear up the State of the Queſtion, by admoniſhing the Reader, that it is not here meant to inquire, why a ſmall Object is thus multiplied when placed without the Limits of diſtinct Viſion; it being evident, that it ought then to appear multiplied, by reaſon that the Eye can never adapt itſelf to its Diſtance. Thus, if I cannot ſee diſtinctly any Object that is nearer than Half a Foot, it muſt appear multiplied at four Inches; And if I cannot ſee an Object diſtinctly that is further off than two Feet, it muſt appear multiplied at three Feet, and all greater Diſtances. But my meaning is to account for this Multiplication, when the Object is placed within the Limits of *diſtinct Viſion*, which we have here ſuppoſed to be at a Foot and a Half Diſtance from each other. And, after various Conjectures on the Matter, I am now, at laſt, fully ſatisfied, that there are two Cauſes that concur in cauſing this *Phænomenon*, by hindering the Eye to accommodate itſelf to the Diſtance of Objects viewed thro' the perforated Card, *viz.* the diſtinct Appearance of the Object, and the Miſtake that the Mind commits with reſpect to its Diſtance.

That the Object appears diſtinct when viewed thro' a perforated Card, is evident from Reaſon as well as from Experience; for the little luminous Cones OHH, O*hh* (ſee ſtill *Fig.* 31.) which have for their *Apex* or Top a Point in the Object O, and for their *Baſis* the little Holes in the Card HH, *hh*, will, by reaſon of their Acuteneſs, proceeding from the Smallneſs of the Holes, take up but a very little Space upon the *Retina*, whence the Object muſt appear pretty diſtinct. Thus, if the Object is at too great a Diſtance, let *o* be the Place where the Rays conveen, and let AB be the *Retina*; it is plain, that the luminous Pencils will fall on the *Retina* at *x* and *x*, where, for the Reaſon juſt now mentioned, they muſt take up but a very little Space; and conſequently the Confuſion muſt be very ſmall. In like manner, if the Object is too near, let CD be the *Retina*, and *o* the focal Point where the Rays are united, theſe Pencils will, at *c* and *c*, occupy ſo ſmall a Space on the *Retina*, as to occaſion no ſenſible Confuſion in the Object; whereas, in both Caſes, had it not been for the Interpoſition of the Card, the luminous Cone *mom*, would, on the *Retina*, have taken up the whole Space *xx* or *cc*, which muſt have rendered the Appearance of the Object very confuſed and indiſtinct. To correct which Confuſion, the Eye changes its Conformation, and adapts itſelf to the Diſtance of Objects ſeen with the naked Eye. But, when by means of the perforated Card, this Confuſion is taken off, the Mind will not then change the Conformation of our Eyes, there being nothing that ſhould influence it to ſuch an Action. And this is one Reaſon why the Object is ſo frequently found multiplied, according to the Number of Holes thro' which it is viewed, tho' it be placed within the Limits of *diſtinct Viſion*, to which the Eye can perfectly accommodate itſelf.

But there is yet another Cauſe which muſt concur towards this Multiplication, and that is, the Miſtake into which the Mind falls with reſpect to the Diſtance of the Object. It is not enough that the Mind perceives no Confuſion: For though this Confuſion in our Sight is commonly believed to be the only thing that can influence our Mind to change the Conformation of our Eyes; yet, by reaſon of that neceſſary Connexion and Dependence, that will be hereafter ſhown to have been eſtabliſhed by Habit and Cuſtom between thoſe Motions, whereby the Conformation of our Eyes is changed, and certain correſponding Motions of the *Axes* of Viſion, theſe Motions come at laſt always to accompany one another, and that ſo neceſſarily as to make it impoſſible for us, by any Act of Volition, to direct our Eyes to any Object within the Limits of diſtinct Viſion, without, at the ſame time, giving them that Diſpoſition that is neceſſary for ſeeing diſtinctly at that Diſtance; and therefore, tho' there ſhould be no Confuſion in the Object, when ſeen thro' the perforated Card, it would not then appear multiplied, if placed within the Limits of diſtinct Viſion, did not the Mind miſtake its Diſtance: For when the Mind judges rightly of the Diſtance of any Object, both Eyes are neceſſarily directed towards it, and that as well when one of them is ſhut, as when both are open; from which Direction of our Eyes, they muſt alſo be accommodated to its true Diſtance: Whence the Object will not appear multiplied, and therefore there muſt be another Cauſe, beſides the diſtinct Appearance of the Object, that muſt concur in this Multiplication; and that is, the Miſtake the Mind commits with reſpect to its Diſtance.

I know that *M. de la* HIRE affirms, that we judge rightly of the Diſtance of Objects viewed thro' a perforated Card; and indeed moſt People, upon Trial, will be apt to fall into the ſame Miſtake; but we will afterwards have

Occaſion to touch upon all the Means the Mind can poſſibly employ for judging of the Diſtance of Objects; from which it will appear, that in the Caſe before us, we can ſcarce form any Judgment with reſpect to Diſtance, but what is wholly founded upon Prejudice and Anticipation, which cannot fail of betraying us into Error and Miſtake. Seeing then that we are ſo liable to be miſtaken in the Judgment we form of the Diſtance of Objects ſeen thro' a perforated Card, it needs be no Surprize that the Eye ſhould not be accommodated to their true Diſtance; and that, for want of this Accommodation, they ſhould appear multiplied according to the Number of Holes thro' which they are viewed.

§ 4. Thus I have fully anſwered the Argument wherein *de la* HIRE places his main Strength, and have ſhown that the Eye may be poſſeſſed of a Power of changing its Conformation, and of adapting itſelf to the Diſtance of Objects, tho' this Power ſhould not be exerted when the Object is viewed thro' a perforated Card. But then our Author alledges, that from an anatomical Examination of all the Parts belonging to our Eyes, it will be found, that none of them are capable of making any of thoſe Changes in the Eye, that are ſuppoſed neceſſary for ſeeing diſtinctly at different Diſtances; but this we ſhall conſider afterwards, when we come to inquire into the Cauſes of theſe inward Motions in our Eyes.

§ 5. There is yet another weighty Argument brought by the learned Author againſt this Change in our Eyes; and that is, that there is no Need of ſuppoſing any ſuch Change; and that the Eye can ſee Objects diſtinctly enough at different Diſtances, ſo as not to be ſenſible of any Defect in the Sight, without being obliged to have Recourſe to any Change in its Conformation.

For underſtanding this, we muſt firſt obſerve, that if an Object appear diſtinct at ſix Feet diſtance, that is, if the Conformation of the Eye be ſuch as is neceſſary to refract the Rays which come from a Point of the Object at that Diſtance, ſo as that, in falling upon the *Retina*, after Refraction, they impreſs it with a diſtinct Image of that Point from whence they came, then at whatever greater Diſtance the Object be placed, it will alſo appear diſtinct: The Reaſon of which is, that when the Object is at ſix Feet Diſtance, the Rays which, in coming from a Point thereof, fall upon the Pupil, are nearly parallel: And therefore at whatever greater Diſtance the Object be placed, the Rays may be conceived as parallel, and conſequently the ſame Conformation of the Eye that is neceſſary to refract them, ſo as to make the Object appear diſtinct at ſix Feet Diſtance, will alſo refract them in the ſame way, and thereby make it alſo appear diſtinct at all greater Diſtances.

Now, this being underſtood, let us ſee how *de la* HIRE accounts for diſtinct Viſion at different Diſtances, without changing the Conformation of the Eye.

Suppoſe then that a Man's Sight is good, that is, that he ſees Objects diſtinctly enough at a Foot Diſtance, and likewiſe at ſix Feet Diſtance; it follows, from what has been ſaid, that to ſee Objects at all greater Diſtances than ſix Feet, there is no Need of any Change in the Conformation of the Eye: So that the only Queſtion is, How the Object can appear diſtinct, both at the Diſtance of ſix Feet, and of one Foot, without ſuffering any Change in its Conformation?

To this the above named Author anſwers, that to ſee Objects ſo diſtinctly, as not to be ſenſible of any Defect in the Sight, it is not needful that the Rays, which come from a Point in the Object, ſhould be united accurately in a Point in the *Retina*, but that it is ſufficient they ſhould be nearly ſo; whence he concludes, that if the Conformation of the Eye be ſuch, as when an Object viewed thro' two Holes in a Card at two Feet Diſtance appears ſingle, becauſe all the Rays that come from the ſeveral Points of the Object are united accurately in ſo many Points in the *Retina*; then, at one Foot Diſtance, the Place where the Rays meet will be a little behind the *Retina*, and at ſix Feet Diſtance it will be a little before it, tho' not ſo much in either Caſe as to render the Object indiſtinct; becauſe the Rays which come from the ſeveral Points in the Object, do, in falling upon the *Retina*, meet nearly, tho' not accurately, in ſo many correſponding Points: And therefore he concludes, that thoſe who have their Eyes of a Conformation proper to ſee Objects moſt diſtinctly at two Feet Diſtance, will alſo ſee them diſtinctly enough both at one Foot Diſtance, and ſix Feet Diſtance; and if they ſee diſtinctly at ſix Feet Diſtance, then they muſt alſo ſee diſtinctly at all greater Diſtances: And thus he accounts for that perfect Viſion which ſtands in the Middle betwixt ſhort and long Sight, without any Change in the Eye.

And as for the Sight of old Men, who cannot ſee diſtinctly at any leſs Diſtance than three Feet, he ſuppoſes that their Eyes are of a proper Conformation to ſee Objects at four Feet Diſtance moſt diſtinctly; from which he infers, that at three Feet and all greater Diſtances, the Picture of Objects upon the *Retina* will be pretty diſtinct, and conſequently they will be ſeen without any ſenſible Confuſion, tho' the Eye ſuffers no Change in its Conformation.

In like manner, in thoſe that are ſhort-ſighted, and cannot ſee Objects diſtinctly at a greater Diſtance than a Foot, he ſuppoſes the Eye to be of a Conformation proper to ſee moſt diſtinctly at Half a Foot's Diſtance, and thence concludes, that the Picture made on the *Retina*, when the Object is at any Diſtance betwixt four Inches and a Foot will not be confuſed; and conſequently the Object will be ſeen diſtinctly enough, without any Change in the Eye, unleſs its Diſtance be greater than a Foot, or leſs than four Inches; in which Caſe the Image on the *Retina* will begin to be confuſed, and conſequently the Object itſelf will alſo appear confuſed and indiſtinct.

§ 6. This is in few Words the Sum of what *de la* HIRE advances, concerning our ſeeing Objects diſtinctly at different Diſtances, without having Recourſe to any Change in our Eyes. And indeed it cannot be denied but the Eye has ſome Latitude of ſeeing Objects diſtinctly, without changing its Conformation, tho' they be a little further from, or nearer to the Eye, than what is neceſſary for collecting the Rays that come from the ſeveral Points of the

Object in ſo many preciſe Points in the *Retina*; and that becauſe when the Object is not far removed from that Place, at which the Rays coming from the Object meet again at the *Retina*, the Image thereof will be pretty diſtinct, and therefore will not occaſion any ſenſible Confuſion of Sight.

But it does not from thence follow, that our Eyes do not change their Conformation, when Objects are much removed from that Place where they appear moſt diſtinctly: For beſides what we have ſaid before, in ſpeaking of the Images of external Objects, caſt upon a Sheet of white Paper, by means of a *Lens* placed at a Hole in the Window-ſhut of a dark Chamber, where we obſerved, that in order to make the Image diſtinct, it was neceſſary, according to the different Diſtance of the Object, either to change the *Lens*, for one more or leſs convex; or to change the Diſtance betwixt it and the Paper, by bringing the Paper nearer to, or further from the *Lens*, according to the different Diſtances of the external Object; I ſay, beſides this, Experience teaches us, that the Conformation of our Eyes is changed, in viewing Objects at different Diſtances. For every body knows, that the Eye cannot ſee equally diſtinctly, at the ſame time, Objects at different Diſtances, *e. g.* If with one of your Eyes, the other being

ing ſhut, you look attentively to a ſmall Object, ſuppoſe a Pin, at Half a Foot or a Foot from the Eye, and at the ſame time place another at ſix Feet Diſtance, that at ſix Feet will appear exceeding confuſed; but if you apply yourſelf to obſerve accurately that at ſix Feet Diſtance, then will appear diſtinctly, but the other next the Eye will appear very confuſed and imperfect; which plainly ſhews, that when the Diſpoſition of the Eye is ſuch as is neceſſary for making a diſtinct Picture of the Pin at one Diſtance, the Place where the diſtinct Picture of the other Pin is made, muſt fall ſhort of, or beyond the *Retina*; and conſequently, upon the *Retina* itſelf the Picture muſt be confuſed, from which Confuſion, Viſion is rendered imperfect and indiſtinct; and therefore, ſince at pleaſure I can ſee diſtinctly either of the Pins I will, while at the ſame time the other appears confuſed, it follows, that I have a Power of changing the Conformation of my Eye, and of adapting it to the different Diſtances of Objects: And this is the only Reaſon can be given, why Objects without Doors do not appear diſtinct thro' a Window-glaſs, when the Eye is attentive in obſerving the little Scratches or Particles of Duſt upon the Surface of the Glaſs: And, on the contrary, when attentive to the external Objects, it does not diſtinctly obſerve the Scratches or opaque

Particles of Duſt upon the Glaſs; the Conformation of the Eye in the one Caſe being ſuch as to paint diſtinctly upon the *Retina* the Images of the Scratches and Particles of Duſt, but not to paint thoſe of the external Objects but confuſedly; and, in the other Caſe, the Conformation of the Eye is adapted to paint exactly upon the *Retina* the Images of external Objects; and therefore the Place, where the diſtinct Images of the Scratches are made, muſt fall behind the *Retina*, from which they muſt appear confuſed and imperfect: And, indeed, were it not for the Change that is made in the Diſpoſition of the Eye, it were very difficult to explain how Birds, that duck in Purſuit of their Prey, ſhould be enabled to ſee both in Air and Water, ſeeing the Refraction that happens in the Eye is ſo far different in the one Caſe from what it is in the other.

To weaken the Force of theſe Objections, *M. de la* HIRE has Recourſe to the Mobility of the Pupil, from which he endeavours to account for diſtinct Viſion at all Diſtances, without any Change in the Conformation of the Eye; but with what Succeſs will appear afterwards when we come to treat of the Motions of the Pupil.

§ 7. Having thus conſidered what *de la* HIRE brings in ſupport of his Hypotheſis, I ſhall now proceed to ſome Experiments I made for meaſuring the Strength and Weakneſs of Sight; whereby not only the Fallacy of *de la* HIRE's Reaſoning will be made further manifeſt; but it will alſo be demonſtrated, beyond all Exception, that our Eyes change their Conformation, and adapt themſelves to the various Diſtances of Objects, within certain Limits; which Limits will alſo be accurately determined: But that theſe Experiments may be the better underſtood, I muſt firſt premiſe the following *Axioms:*

AXIOM I.

When an Object, ſeen with both Eyes, appears double, by reaſon that its Diſtance is leſs than that to which the Eyes are directed, upon covering either of the Eyes, the Appearance that is on the contrary Side will vaniſh; and if it appear double, becauſe its Diſtance is greater than that to which the Eyes are directed, upon covering either of the Eyes, the Appearance that is on the ſame Side will vaniſh.

ILLUSTRATION. To illuſtrate this, (See *Fig.* 32. 33. and 34. PLATE. IV.) where A and B are the Eyes, *x* the Object, which is at a ſmaller Diſtance than the Point C, to which both Eyes are directed: It is evident, that while the Eyes continue directed to C, the Object *x* muſt be ſeen in two different Places, which, with reſpect to the *Horopter*, to which all Objects are referred, will be D and E; for, being ſeen by the Right-eye B, in the Direction of the viſual Line B*x*D, it muſt, at D, hide a Part of the *Horopter* DCE; and being ſeen by the Left-eye A, in the Direction of the viſual Line A*x*E, it muſt hide a Part of the *Horopter* at E; and therefore, with reſpect to the *Horopter*, on which the Eyes are fixed at C, the Object *x* muſt appear to the Right-eye B, as at D, and to the Left-eye A, as at E; and, in covering either of the Eyes, the Appearance that is on the contrary Side will be made to vaniſh.

In like manner, if the Eyes are directed to *x*, the Object C, which is further off than *x*, will be ſeen by the Right-eye B, in the Direction of the viſual Line B*m*C; and by the Left-eye A, it will be ſeen in the Direction of the viſual Line AOC: And therefore, with reſpect to the *Horopter m x*O, to which all Objects are referred, it muſt appear double, as at *m* and O; and in covering the Right-eye B, the Appearance that is on the right Side towards *m* will vaniſh; and in covering the Left-eye A, the Appearance that is on the left Side towards O will vaniſh: All which is exactly agreeable to Experience.

AXIOM II.

When an Object appears double, from its being ſeen with one Eye thro' two ſmall Holes made in a Card, or any other opaque thin Body, if its Diſtance be greater than that to which the Eye is accommodated, upon covering either of the Holes, the Appearance that is on the ſame Side will be made to vaniſh; and if its Diſtance be leſs than that to which the Eye is accommodated, upon covering either of the Holes, the Appearance that is on the contrary Side will be made to vaniſh.

ILLUSTRATION. Let E be the Eye, (See PLATE V. *Fig.* 35. and 36.) QT the Card, in which are two ſmall Holes *d* and *r*, and let A be a ſmall Body, at a greater or leſſer Diſtance than that to which the Eye is accommodated; the Rays of Light A*d*, A*r*, will not, after Refraction, converge to a Point in the *Retina*; but, by reaſon that the Diſtance of the Object A is greater or leſs than that to which the Eye is accommodated, they will be made to converge to ſome other Point, either before or behind the *Retina*, ſuch as *o*; but on the *Retina* itſelf they will fall on the different Points *i* and *m*, at both which a Picture of the Object will be formed; from which Duplication of the

Picture the Object itſelf will alſo appear double at C and B, *viz.* in the right Lines *i*C and *m*B, which are ſuppoſed to be drawn perpendicular to the *Retina* from the Points *i* and *m*, where the Pictures fall. Whence it is evident, that if the Hole at *d* be covered, there will be no Image at *i*, and conſequently the Appearance at C will vaniſh; and if the Hole at *r* be covered, there will be no Image at *m*, and conſequently the Appearance at B muſt vaniſh: But, when the Object A is at a greater Diſtance than that to which the Eye is accommodated, as in *Fig.* 35. the Appearance that is made to vaniſh, by covering either of the Holes *d* or *r*, lies on the ſame Side with the covered Hole. But, when the Object A is at a leſs Diſtance than that to which the Eye is accommodated, as in *Fig.* 36. the Appearance that is made to vaniſh lies on the contrary Side of the Hole that is covered; as has been affirmed in the Axiom.

EXPER. I. I took a ſmall Plate of white Iron IK, (See PLATE V. *Fig.* 37.) in which I cut two parallel narrow Slits, whoſe Diſtance from one another did not exceed the Diameter of the Pupil. Theſe Slits gave Paſſage to more Light than what could paſs thro' the Holes; and therefore were fitter for my Purpoſe, it being neceſſary that the Object ſhould be clearly ſeen. This Plate I held cloſe to my Right-eye B, in ſuch manner as the Slits might have a vertical Poſition; and having ſhut my Left-eye A, thro' theſe Slits I viewed the ſmall Object O, which alſo had a vertical Poſition, and conſequently was parallel to the Slits. In this Experiment the Object O was at ſuch a Diſtance from the Eye B, as to appear ſingle, when viewed in this manner thro' the Slits: But, when both Eyes were opened, and directed to a more diſtant Point, ſuch as P, three Appearances were ſeen, *a*, *b* and C; which Appearances were nearer to, or further from each other, according as the Point P was nearer to, or further from the Object O; and in covering the Left-eye A, the Appearance *a*, that was on the contrary Side, did vaniſh; which Appearance did therefore belong to the Eye A. And, in covering the right Eye B, the Appearances on the contrary Side *b* and C, belonging to the Eye B, did vaniſh; from which I was certain, that the Diſtance of the Object O was leſs than that to which the Eyes were directed. (See *Ax.* 1.) This being done, my next Buſineſs was to examine, whether theſe double Appearances *b* and C, that were ſeen thro' the Slits, did not alſo proceed from the Object O its being at a leſs Diſtance than that to which the Eye B was then accommodated; and upon Trial I found it was ſo; for, by covering either of the Slits with my Finger, the

Appearance on the contrary Side was always made to vaniſh. (See *Ax.* 2.)

Having ſatisfied myſelf as to theſe Particulars, I changed the Direction of my Eyes, and turned both inwards towards a nearer Point, ſuch as *x*; by which alſo three Appearances were ſeen *d*, *e* and F; and theſe Appearances were alſo nearer to, or further from one another, according as the Point *x* was nearer to, or further from the Object O; but they were always in a contrary Order to thoſe that were ſeen, when my Eyes were directed as above: For the Appearance F, ſeen by the Left-eye A, was on the left Side, and the Appearances *d* and *e*, which were ſeen thro' the Slits by the Right-eye B, were on the right Side; whence I was certain, that the Diſtance of the Object O was greater than that to which my Eyes were directed. I then covered one of theſe Slits with one of my Fingers, and I found that the Appearance that was on the ſame Side did always vaniſh; from which, when compared with the ſecond Axiom, it follows, that the Object O is then at a greater Diſtance than that to which the Eye is accommodated.

In making this and all the following Experiments, it was neceſſary that the Object O ſhould be as conſpicuous as poſſible: What upon trial I found to anſwer beſt, was a narrow Slit made in a dark Lantern, in which a lighted

Candle was put, to render it luminous, tho' ſometimes I alſo made uſe of a black Line upon white Paper, or a white Line upon black Paper; both which anſwered very well in all the Experiments wherein the Diſtance of the Object did not exceed two Feet; but when the Diſtance was greater, theſe Lines began to be obſcure, and by reaſon of their Obſcurity, the Experiment did not ſucceed ſo well.

It muſt alſo be obſerved here, once for all, that tho', in the above Experment, it was eaſy for me to direct my Eyes to a Diſtance that was either greater or leſs than the Diſtance of the Object O, without the Aſſiſtance of any other Object, on which my Eyes might be fixed; yet in this, as well as in many of the ſubſequent Experiments, I was ſometimes obliged to put an Object in that Place, towards which both Eyes were to be directed; and this was always neceſſary, either when a great Effort was needful to give the Eyes the deſigned Direction, or when, for obſerving the *Phænomena* more accurately, the Experiment required that the Eyes ſhould for ſome Time be kept fixed in a certain determined Direction; both which are made much eaſier, by having an Object on which the Eyes may be fixed. When it was required that my Eyes ſhould be directed to a very near Diſtance, for the

Object O, I made uſe of a black or white Line, made on Paper of an oppoſite Colour; and at the Place *x*, to which my Eyes were to be directed, I held in a horizontal Poſition, and parallel to my Eyes, any ſmall Object *zx*, ſuch as a Bit of the Stem of a Quill, whoſe Extremity *x* I looked at for an Object; but when the Experiment required that my Eyes ſhould be directed to ſome Point at a conſiderable Diſtance beyond the Object O, for the Object O, I made uſe of the narrow Slit in the Lantern; and at the diſtant Point P, to which my Eyes were to be directed, I placed another dark Lantern, in which was the horizontal Slit PQ, whoſe Extremity P, which was ſeen by the Right-eye, in the viſual Line BOP that paſſed immediately above the upper End of the Object O, ſerved me as a Point of View, on which I could eaſily fix both Eyes, while I attended to the Appearance of the Object O.

Now, from this Experiment, compared with the preceeding Axioms, it clearly follows,

1*mo*, That we are poſſeſſed of a Power of changing the Conformation of our Eyes, and of adapting them to various Diſtances.

2*do*, This Change in our Eyes, whereby they are fitted for ſeeing diſtinctly at different Diſtances, does always follow a ſimilar Motion in the Axes of Viſion, with which it has been connected by Uſe and Cuſtom; for, when the Eyes were directed to P, the Object O was ſeen double thro' the Slits, and by covering one of the Slits, it appeared that the Eye was adapted to too great a Diſtance; and as the Point P was brought nearer and nearer the Object O, theſe Appearances approached nearer and nearer to one another continually, till at laſt, when the Point P became very nigh to O, they coincided in one at O; which ſhews that the Eye was then adapted to its Diſtance. But when the Point P was moved along the Line O*x*, from O to *x*, two Appearances of the Object O were again ſeen thro' the Slits; which Appearances being in a contrary Order from what were ſeen, when the Point P was on the other Side of the Object O, it follows, that the Eye was then adapted to too ſmall a Diſtance. And as the Point P, in its Motion from O to *x*, receded further and further from O theſe Appearances receded further and further from one another continually. From all which, it is evident, that there is a neceſſary Connection and Dependence eſtabliſhed betwixt thoſe Motions, whereby the Conformation of our Eyes is changed, and certain correſponding Motions in the Axes of Viſion, which makes it impoſſible for us to direct our Eyes to any Object within the Limits of diſtinct Viſion, without at the ſame time giving them that Diſpoſition that is neceſſary for ſeeing diſtinctly at that Diſtance; but theſe two Corollaries will be ſtill further confirmed by the Experiments that follow.

EXPER. 2. The Diſtance of the Object O (ſtill *Fig.* 37.) being 5 Inches, I viewed it thro' the Slits, the other Eye A being ſhut or covered, and it appeared double; and, upon covering either of the Slits, the Appearance that was on the contrary Side was made to vaniſh, and therefore the Diſtance of the Object was leſs than that to which the Eye was accommodated; and both Eyes being open, and directed to *x*, whoſe Diſtance from the Eye was about three or four Inches, three Appearances were ſeen, *d*, *e* and F, whereof the Appearances *d* and *e* belonged to the Right-eye B, and when with my Finger I covered either of the Slits, the Appearance that was on the contrary Side did vaniſh; whence it is evident, that I cannot, by any Effort, fit my Eyes to ſo ſmall a Diſtance as five Inches.

EXPER. 3. 4. and 5. At ſix, ſeven and eight Inches Diſtance, when one Eye was ſhut, the Object O, ſeen thro' the Slits, appeared double; and by covering one of the Slits, it was evident that its Diſtance was leſs than that to which the Eye was accommodated. And in looking with both Eyes to *x*, whoſe

Diſtance from the Eye was about Half the Diſtance of the Object O, a double Appearance was ſeen, one at F, belonging to the Eye A, and the other at *x*, belonging to the Eye B; but this Appearance at *x* was always ſingle, tho' ſeen thro' the Slits; whence it follows, that my Eye cannot accommodate itſelf to a Diſtance that is much leſs than ſix, ſeven or eight Inches.

EXPER. 6. At the Diſtance of nine Inches, the Object O, ſeen thro' the Slits, the other Eye being ſhut, appeared ſometimes ſingle, but moſtly double; and when it appeared double, it was evident, by covering either of the Slits, that it was too near, with regard to the Diſpoſition of the Eye; and when both Eyes were open, and directed to the Quill *x*, which was at Half the Diſtance preciſely, three Appearances were ſeen, whereof the Appearances *d* and *e* did belong to the Right-eye B, to which the Slits were applied; and in covering one of thoſe Slits, the Object on the ſame Side diſappeared: Whence I was certain, that the Object was too far off, and that my Eye can be accommodated to a leſs Diſtance than nine Inches, but not much, as may be learned from the Nearneſs of the Appearances, as well as from the four laſt Experiments.

From the five laſt Experiments laid together, we may ſafely draw the following Corollary, *viz.*

The neareſt Limits of diſtinct Viſion, in my Eyes, is at about ſeven Inches Diſtance; for, by the ſecond Experiment, it appears, that my Eyes cannot be fitted to ſo ſmall a Diſtance as five Inches; and by the laſt Experiment it is plain, that they can be accommodated to a leſs Diſtance than 9 Inches; and the third, fourth and fifth Experiments make it manifeſt, that, at ſix, ſeven, and eight Inches Diſtance, the Object ſeen thro' the Slits appears always ſingle, whatever Effort be made to double it, by ſtraining the Eyes to ſee a nearer Object; whence, the middle Diſtance ſeven Inches, ſeems to be nearly the neareſt Limits of my Eye, beyond which it cannot go; and therefore, all Objects that are nearer than ſeven Inches, muſt appear more and more confuſed, according as their Diſtance is leſs and leſs than ſeven Inches.

Exper. 7. In looking to an Object at two Feet Diſtance thro' the Slits, the other Eye being ſhut, it always appeared double and too far off, and in looking with both Eyes to a more diſtant Object, it was then alſo ſeen double; but, in covering either of the Slits, the Appearance on the oppoſite Side did vaniſh: Whence it was evident, that the Object was then too nigh; but theſe Appearances were ſo cloſs, that they did almoſt touch one another; which ſhews, that my Eyes can ſcarce go further, than to accommodate themſelves to the Diſtance of two Feet.

EXPER. 8. At two Feet and a Half, three Feet, and all greater Diſtances, the Object O not only appeared double and too far off, when viewed with one Eye thro' the Slits; but when both Eyes were open, and directed to a very diſtant Object, the double Appearance that was then ſeen thro' the Slits, was ſuch, as by covering one of the Slits, made it evident, that even then the Object was too far off; from which it follows, that my Eyes can never by any Effort be accommodated to ſo great a Diſtance as two Feet and a Half.

COROL. From this, and the immediately preceeding Experiment, it ſeems probable, that the furtheſt Limits of my Sight reaches to the Diſtance of about 27 Inches; for, by Experiment 7. it is plain, that I can accommodate my Eye to a Diſtance that is greater than two Feet, and by the laſt Experiment it is manifeſt, that my Eye cannot accommodate itſelf to ſo great a Diſtance as two Feet and a Half: Whence it ſeems reaſonable to conclude, that the furtheſt Limits of my Sight lies about the middle Diſtance betwixt both.

EXPER. 9. and 10. At ten and twelve Inches Diſtance, the Object O, ſeen with one Eye thro' the Slits, did, as in Experiment 6. where it was at the Diſtance of nine Inches, appear ſometimes ſingle, but frequently double and too nigh.

EXPER. 11. and 12. At the Diſtance of fifteen and eighteen Inches, one Eye being ſhut, the Object O, ſeen thro' the Slits, appeared ſometimes ſingle, and at other times double; but when it was double, by covering one of the Slits, it was always found to be too far off.

COROL. From the four laſt Experiments, as well as from ſome of the preceeding ones, it is manifeſt, 1*mo*, That the Eye does frequently miſtake the Diſtance of the Object ſeen thro' the Slits; for when its Diſtance lies betwixt the Limits of diſtinct Viſion, to which the Eye can eaſily accommodate itſelf, it would never appear double did not the Mind miſtake its Diſtance. And this is the Reaſon why, when both Eyes are open and directed to the Object, it appears ſingle at all Diſtances within the Limits of diſtinct Viſion, by Reaſon the Eye is then accommodated to its Diſtance; which is then known to us by means of the Angle which the optic Axes make at the Object.

2*do*, The Judgment which the Mind forms with reſpect to the Diſtance of Objects, ſeen with only one Eye thro' the Slits, is not always the ſame, but is fluctuating and inconſtant, as may be gathered from the four laſt Experiments, where the Object ſometimes appeared ſingle, and at other times double; and when it appeared double the Diſtance betwixt the Appearances was not conſtantly the ſame.

3*tio*, If the Object ſeen thro' the Slits, the other Eye being ſhut, is not much beyond the neareſt Limits of diſtinct Viſion, when the Mind miſtakes its Diſtance, it imagines it further off than it really is; as is evident from the 4th, 5th, 6th, 9th, and 10th Experiments. But,

4*to*, When the Object is not a great deal nearer than the furtheſt Limits of diſtinct Viſion, when we miſtake its Diſtance, we imagine it nearer than it really is; whence it apppears double, becauſe it is too far off with reſpect to the Conformation of the Eye; as does appear from the 7th, 11th, and 12th, Experiments.

If it ſhould be here inquired, why the Mind miſtakes the Diſtance of the Object ſeen thro' the Slits, the other Eye being ſhut? To this I anſwer, that by running over all the Means the Mind can poſſibly employ for judging of the Diſtance of Objects, which Means we will have occaſion to touch upon below, it will appear, that, in the Caſe before us, we can ſcarce form any Judgment with reſpect to Diſtance, but what is intirely founded upon Prejudice and Anticipation: And therefore, it needs be no Wonder, that we are frequently led into Error and Miſtake, and that the Mind ſhould be ſo fluctuating and inconſtant in the Judgment it forms of Diſtance.

When I made the foregoing Experiments, I deſigned to repeat them with more Care and Exactneſs, and to make ſome new ones of the ſame Sort, by Means of an Inſtrument I had contrived for that Purpoſe; which, from its Uſe in meaſuring the Limits of diſtinct Viſion, and in determining with great Exactneſs the Strength and Weakneſs of Sight, may be called an *Optometer*; but I was then interrupted, and I have not now time to take thoſe things into further Conſideration; thoſe who deſire ſuch an Inſtrument, may eaſily make one from what has been above ſuggeſted.

§ 8. Having thus ſufficiently demonſtrated, that our Eyes do change their Conformation, and adapt themſelves to the different Diſtances of Objects, it remains, that we examine wherein this Change conſiſts, and by what Mechaniſm it is introduced; about which Authors are very much divided in their Opinions; the chief of which we ſhall now conſider, and fix upon what we think moſt probable, leaving every Body at Liberty to differ from us, as he ſees Reaſon.

Some are of Opinion, that the whole Globe changes its Figure, by being lengthened into an oblong Figure, when Objects are near; and by becoming flat, when they are removed to a greater Diſtance. This indeed very well accounts for the diſtinct Appearance of Objects at different Diſtances; for according as Objects are nearer or further from our Eyes, their Images will be painted at different Diſtances behind the cryſtalline Humour. And therefore, if we have a Power of rendering the Eye flat or oblong, the *Retina* will be brought to that preciſe Place behind the Cryſtalline, where the perfect Image of the Object is made, and conſequently will be ſeen diſtinctly.

Now, this Change in the Figure of the Eye is differently explained by Authors: Some maintain, that it is rendered oblong, by the joint Contraction of the two oblique Muſcles; and this Opinion Dr. KEILL likewiſe embraces. His Words are: "The aqueous Humour being the thinneſt and moſt liquid, "eaſily changes its Figure, when either the "*Ligamentum Ciliare* contracts, or both the "oblique Muſcles ſqueeze the Middle of the "Bulb of the Eye, to render it oblong, when

" Objects are too near us." (See his *Anat. chap.* iv. *Sect.* 4.)

But this is by no Means probable; for, in order that the Eye may be rendered oblong by the Contraction of theſe Muſcles, it is neceſſary to ſuppoſe, that they preſs its Sides inward towards its *Axis*; but this they cannot perform, becauſe, their Diſpoſition is not proper for that Effect: Had they been ſo diſpoſed as to embrace the Globe in the Form of a Ring, their Contraction might then have ſqueezed the Eye into an oblong Figure; but their preſent Diſpoſition is very far different from what ſeems neceſſary for producing this Change in the Eye, which we ſhall not now repeat, having, in treating of the *External Motions* of this Organ, deſcribed them at ſome Lenght.

But beſides this, there is yet another Argument againſt the Eye's changing its Conformation, when theſe Muſcles contract; and that is, that in ſeveral Creatures their Diſpoſition is very far different from what it is in Man: Thus, in the Pike, they are both ſituated in the under Side of the Eye, where they decuſſate one another in Form of a Croſs, as has been already obſerved from AQUAPENDENT and PERRAULT: In the *Caris Carcharias*, and in ſome other Fiſhes of the Dog-kind, STENO has obſerved, that the *ſuperior Oblique* had no *Trochlea*, but that its Origin and Progreſs was altogether ſimilar to the *inferior Oblique*. (See his *Canis Carchariæ diſſectum Caput*, and his *Diſſectio Piſcis ex Canum genere*). And PEYERUS the Son, in his *Obſervationes Anatomicæ*, tells us, that the *grand Oblique* is alſo without any *Trochlea* both in Geeſe and Hares; whence it ſeems improbable, that theſe Muſcles ſo differently diſpoſed, in different Animals, do ever ſqueeze the Eye, ſo as to render it oblong; and yet it muſt be allowed, that they have a Power of accommodating their Eyes to the different Diſtances of Objects, as well as other Creatures; which therefore muſt be ſought for ſome where elſe than in the *oblique Muſcles*.

§ 10. Another Opinion concerning this Change of our Eyes is, that the four *ſtreight Muſcles*, acting together, compreſs the Sides of the Globe, and by this Compreſſion, reduce it to an oblong Figure, when Objects are near; and that by its natural Elaſticity it recovers its former Figure, when theſe Muſcles ceaſe to act.

But tho' this Opinion be received by the learned BOERHAAVE, as well as by the Generality of other Authors, yet there are many Objections, which render it very doubtful, if not altogether abſurd: For when theſe Muſcles act together, they muſt draw the Eye inwards, and preſs its Bottom againſt the Fat, which touches it in that Place: But all Action and Re-action being equal, it follows, that the Back-part of the Eye muſt be preſſed forwards by the Fat, with as much Force as the Muſcles draw the Eye inwards; and conſequently, that the Force whereby theſe Muſcles endeavour to lengthen the Eye, by compreſſing or ſqueezing its Sides, muſt be balanced and taken off, by the Preſſure of the Fat, againſt the Back-part of the Eye. The other Objections againſt this Hypotheſis muſt be taken Notice of below, to which the Reader muſt therefore be referred for ſaving Repetitions.

§ 11. Others are again of a quite contrary Opinion, and would perſuade us, that when theſe four *ſtreight Muſcles* act together, they render the Eye flat, by pulling it inwards, and preſſing its Bottom againſt the Fat, and that it is again reduced to its former Figure, either by the joint Contraction of the two *oblique Muſcles*, or by the inherent Elaſticity of its Parts, which exerts itſelf when the *ſtreight Muſcles* ceaſe to act.

But neither does this Opinion appear probable; for, when theſe Muſcles contract, they not only endeavour, by preſſing the Eye againſt the Fat in the Bottom of the Orbit, to render it flat, but likewiſe ſqueeze the Sides of the Eye, and by that means endeavour at the ſame time to render it oblong, which two Actions being equal, becauſe proportional to the ſame Cauſe, *viz.* the Contraction of the Muſcles, and being contrary to one another, they muſt deſtroy each other.

From what has been ſaid, it ſeems very probable, that the Eye can neither become flat nor oblong, either by the Action of the *ſtreight* or *oblique Muſcles.* And this does yet further appear from the following Reaſons:

1*mo*, Did the Eye accommodate itſelf to the Diſtance of Objects, by any Change in its Figure, ariſing from the Contraction of its Muſcles, this Change would be different in different Poſitions of the Eye, and only regular in one Situation of it.

2*do*, If you preſs your Eye gently with your Finger, all Objects ſeen with that Eye will appear confuſed and indiſtinct, neither will they appear more perfect, at whatever Diſtance they be placed. If you aſk the Reaſon of this *Phænomenon*, I know no better Anſwer, than that that determined Situation of the ſmall Fibres compoſing the *Retina*, which is neceſſary for diſtinct Viſion, is by the Preſſure of the Finger diſturbed and diſordered: And therefore, it is not eaſy to underſtand, how the ſame Diſpoſition ſhould not be equally diſordered by that ſuppoſed Compreſſion of the Muſcles, which is neceſſary for changing the Figure of the Eye.

§ 13.

§ 13. 3*tio*, A third Argument againſt this Change of Figure in the Eye, is, that in ſome Creatures the *Sclerotica* is ſo very hard as does not allow of any ſuch Change; and this Diſpoſition in the *Sclerotica* is generally obſervable in all Birds and Fiſhes, both which have it bony, from the middle of the Globe, to its Fore-part, where it joins the *Cornea*, as has been obſerved by AQUAPENDENT, the *French Academiſts*, and many other Anatomiſts. Mr. RANBY has obſerved, that this bony Circle in the Oſtrich conſiſts of fifteen bony Scales joined to one another, ſo as to make one circular Bone round the *Cornea*, of which he has given a Figure in the *Philoſophical Tranſactions*. And Mr. WARREN has ſince found, that the Oſtrich has this Ring in common with other Fowls, both of the Water and Land, with this Difference only, that the Ring in Water-Fowls conſiſts of fifteen, and in Land-Fowls but of fourteen Bones, and that they are ſo diſpoſed, that one Bone lies over the Ends of two others, then three or four lie over one another like the Scales of Fiſh; then one Bone lies under the Ends of two others, and then two or three more follow again, like the Scales of Fiſh; but he thinks, that unleſs there be a *Luſus Naturæ*, Mr. RANBY's Figure does not expreſs it ſo very juſtly as it might be done; which RANBY himſelf in another Paper ſeems to acknowledge. (See *Philoſoph. Tranſ. Abrid. Vol.* VI.) But whatever be in this, one Thing is certain, that in all Fowls, as well a Fiſhes, a great part of the *Sclerotis* is hard and inflexible: And particularly in the Owl, Mr. PERRAULT ſpeaks as if it were wholly bony, yet I find, that PEYERUS the Son makes it a little ſofter towards the Entry of the optic Nerve. But what makes moſt for our Purpoſe, is, that in ſome Fiſhes the whole of the *Sclerotica* is of a cartilaginous or bony Subſtance; thus it is in the Whale, in which alſo its Thickneſs is more than an Inch, as RUYSCH obſerves, (*Theſaur. Anatom. Maxim.* N° LI.) In the Sea-Fox, this Tunicle, tho' thin, was by the *French Academiſts* found "ſo "hard that it might rather paſs for a Bone "than a Cartilage." (*See their Memoirs for the natural Hiſtory of Animals.*) And the like has been obſerved by STENO, in the *Canis Carcharias*, and ſome other Fiſhes of the Canine Kind, "*Sclerodis tunicæ pars anterior, et "tranſlucens,* (ſays he in his *Canis Carchariæ "diſſectum Caput*) *quæ Cornea dicitur, hic plana "erat, reliqua pars vere dura, cæteris in eodem piſ"ce cartilaginibus ſimilis; ſic et in avibus, magna "ſclerodis pars oſſea reperitur, &c.*" SANCTORINI, in his *Obſervationes Anatomicæ,* (*cap.* IV. *ſect.* 2.) has alſo a very remarkable Obſervation to the ſame Purpoſe: His Words are, *Quoniam nulla* *ſunt, quæ circa oculi muſculos adnotanda habemus, de eorundem uſu quædam proponere libet: Num ſcilicet, præter ejuſdem oculi motum, illum ſic vel retrahant vel producant, ut vel in planiorem, vel in acutiorem figuram ille conformetur? Hanc me in quæſtionem induxit oſſeam prorſus reperiſſe in Thinni oculis ſclerotidem membranam, ob cujus quidem ſoliditatem ac duritiem, nullo muſculorum vel valentiſſimo niſu conſtituta poteſt figura commutari. Quapropter ſi in eo piſce quidquam commodi ex ejus figuræ varietate natura ſperaviſſet, aliud quodpiam artificium in ejus vicem machinata fuiſſet, &c.* Now, from theſe Obſervations, it is very plain, that in many Animals it is impoſſible that the Eye can accommodate itſelf to the different Diſtance of Objects, by varying its Figure, the Action of its Muſcles being inſufficient to overcome the Reſiſtance of its cartilaginous or bony and almoſt inflexible Tunicles; and yet it cannot be denyed but they have a Faculty of changing the Conformation of their Eyes, and of adapting them to the Diſtance of Objects, as well as other Creatures, which therefore we muſt expect to find ſomewhere elſe than in any of its Muſcles.

It may indeed be ſaid, that tho' the Change made in the Eyes of Birds and Fiſhes, does not proceed from the Action of its Muſcles, yet it does not from thence follow, that in Man and other Animals who have the Tunicles of the Eye flexible and yielding, the Contraction of theſe Muſcles does not produce ſome Variation in the Figure of the Eye: This I readily own; yet, if we conſider, that Nature is very conſonant and conformable to herſelf in all her Actions, we can hardly doubt but the ſame Cauſe, which, in Fiſhes and Birds, accommodates their Eyes to the diſtinct Viſion of Objects at different Diſtances, does likewiſe produce the ſame Change in the Eyes of Men, eſpecially ſince there is nothing to be found in the Eyes of theſe Creatures, capable of producing that Change, but what alſo obtains in human Eyes.

I am not ignorant, that ſome have feigned certain Fibres going from the *Choroides* to the Cryſtalline in Birds; and others have ſuppoſed, that in Fiſhes there is likewiſe ſome peculiar Diſpoſition for adapting their Eyes to the Diſtances of Objects. But with reſpect to Birds, PERRAULT, and the *French* Academiſts have particularly obſerved, that there are no ſuch Fibres different from thoſe that compoſe the *Marſupium nigrum*, which can never anſwer that End, being adapted to another Purpoſe, to be explained afterwards; and as for Fiſhes, that pretended Mechaniſm is ſo darkly explained, and that only by Authors of ſo little Character and Reputation, that it does not deſerve Credit. But,

§ 14. 4*to*, To put this Matter out of all Diſpute, we muſt have recourſe to the following Obſervation, *viz.* A Man having a Cataract in both Eyes, which intirely deprived him of Sight, committed himſelf to an Oculiſt, who finding them ripe, performed the Operation, and couched the Cataracts with all the Succeſs could be deſired; but after they were couched, he could not ſee Objects diſtinctly, even at an ordinary Diſtance, without the Help of a very convex *Lens*; which is what every body has obſerved to be neceſſary to all thoſe who have had a Cataract couched: Neither is the Reaſon thereof difficult; for as a Cataract is not a Philm ſwimming in the aqueous Humour, as has been generally believed, till of late, but an Opacity in the Cryſtalline itſelf; and as the couching of a Cataract conſiſts in introducing a Needle into the Eye, and turning down the opaque Humour below the Pupil, it is evident that the Cryſtalline cannot be diſplaced and turned down to the under Part of the Eye, but the vitreous Humour muſt, in giving way to it, be puſhed into its Place; but becauſe its Denſity is leſs than that of the Cryſtalline, it follows, that the Rays of Light will be leſs refracted, and therefore will not meet at a Point in the *Retina*, but at ſome Diſtance behind it; from whence the Sight muſt be confuſed, unleſs a convex Glaſs of a due Degree of Convexity be brought to Aſſiſtance, which, by refracting the Light, may render its Rays leſs diverging, and thus ſupply the Refraction which is wanting in the Eye by the Depreſſion of the Cryſtalline; and this is the true Reaſon why there can be no diſtinct Viſion after the couching of a Cataract, unleſs when Objects are viewed through a convex Glaſs of a due Degree of Convexity; nor has the Efflux of the aqueous Humour any Concern in this *Phænomenon*, ſeeing it is again reſtored, as was known to GALEN, as before obſerved: But this is not all that happens after the Depreſſion of the Cataract; for it was alſo obſerved, that the ſame *Lens* was not equally uſeful for ſeeing all Objects diſtinctly, but that he was obliged, for ſeeing them diſtinctly, to uſe Glaſſes of different Degrees of Convexity, ſtill the more convex the nearer the Object.

To make this Experiment with great Exactneſs, and to provide againſt all Poſſibility of Miſtake, it were proper to cover that Side of the *Lens* that is next to the Eye with black Paper, in the Middle of which, two narrow parallel Slits have been made, whoſe Diſtance from one another does not exceed the Diameter of the Pupil. By this means, if the Eye ſtill retains its Faculty of changing its Conformation, a ſmall Object, that is at ſuch a Diſtance as to appear ſingle through the Slits, when the other

Eye is ſhut, may be made to appear double, by opening both Eyes, and directing them to a nearer or more remote Object, as has been explained above; whence, if no ſuch double Appearance can be ſeen, we may conclude, with great Certainty, that the Eye has loſt its Power of accommodating itſelf to the Diſtance of Objects. I have never had an Opportunity of making the above Experiment myſelf; but when any ſuch offers, I deſign to make it in this Manner, or rather to employ the Inſtrument formerly mentioned; which, for its Uſe in meaſuring the Limits of diſtinct Viſion, and in determining with the utmoſt Exactneſs the Strength and Weakneſs of Sight, I have called an *Optometer*. In the mean time, from the Experiment, as it ſtands, we may ſafely draw the following Corollaries:

COROL. 1. From what happens in couching the Cataract, the Eye loſes the Faculty of adapting itſelf to the various Diſtances of Objects.

COROL. 2. Did that Change in the Eye, that is neceſſary for ſeeing Objects at different Diſtances, depend upon the Action of its Muſcles, then, after the Depreſſion of a Cataract, the ſame *Lens* will anſwer all Objects of whatever Diſtance; but ſince this is not Fact, it follows, that however the Muſcles of the Eye may be ſuppoſed to change a little its Figure, yet this Change is not ſufficient to provide for the diſtinct Viſion of Objects at all Diſtances.

Corol. 3. Seeing that nothing happens in the Eye, in couching the Cataract, but that the Cryſtalline is depreſſed, it follows, that the Change made in our Eyes, according to the Diſtance of Objects, muſt be attributed to this Humour.

§ 15. It remains now that we inquire what this Change of the Cryſtalline is, and by what Mechaniſm it is produced.

Some maintain, that according as Objects are at different Diſtances, this Humour becomes more or leſs convex, which does indeed very well account for diſtinct Viſion at all Diſtances; for Objects painted on a Sheet of white Paper, by means of a *Lens* placed in the Hole of a Window-ſhut of a dark Chamber, have their Images always diſtinct, at whatever Diſtance they be from the Window, provided that the *Lens* be of a Convexity anſwerable to that Diſtance.

Others again are of Opinion, that the Cryſtalline never changes its Figure, but that it is moved to and from the *Retina*, according to the Diſtance or Proximity of the Object in View; and this alſo does equally well account for the diſtinct Appearance of Objects at all Diſtances, as is evident from the Laws of Optics, as well as from the vulgar Experiment of caſting the

Species of Objects from abroad upon a Sheet of white Paper, by means of a *Lens* placed at a Hole in the Window-ſhut of a dark Chamber: For the Picture will always be diſtinct, at whatever Diſtance the Object may be, provided that the Paper be at a due focal Diſtance behind the *Lens*.

Thoſe that embrace the firſt Opinion ſay, that the *Ligamentum Ciliare*, which ariſes all round from the Inſide of that Circle of the *Choroides* where it joins the *Uvea*, does by its Contraction draw the Edge of the Cryſtalline, to which it is attached all round, towards that Circle; and by that means makes it broader and flatter than before, when Objects are at a Diſtance from the Eye; and that when we view nearer Objects, this Ligament is relaxed, and the Cryſtalline recovers its Convexity by the Elaſticity of its Parts: And to render this Opinion ſtill the more probable, they contend, that it is for this End that Nature has made the outer Part of this Humour of a Subſtance eaſily flexible and yielding, that it may with greater Facility yield to the Contraction of this Ligament.

But, if we obſerve accurately the Situation of the *Ligamentum Ciliare*, we will find, that it is ſuch as diſqualifies it for rendering the Cryſtalline more flat, by increaſing its Breadth; for its Fibres are not in the ſame Plane with the Cryſtalline, but have an oblique Direction, as in (*Fig.* 38. PLATE V.) where C is the Cryſtalline Humour, *a*C*a* its tranſverſe Diameter, *ao*, *ao* the *Ligamentum Ciliare* (ſometimes alſo called the *ciliary Proceſs*). Now, in order to draw out the Cryſtalline into a broad flat Figure, or, which is a juſter Way of conceiving this Matter, in order to draw out and extend its Capſule, ſo as it may compreſs the Cryſtalline into this Figure, it ſeems neceſſary it ſhould be drawn according to the Direction of the Lines *ab* and *ab*, which are in the ſame Plane with the tranſverſe Diameter of this Humour *a*C*a*; but this cannot be performed by the *Ligamentum Ciliare*, becauſe its Direction is oblique; and therefore it can never by its Contraction change the Figure of the Cryſtalline.

§ 16. Nor is this Opinion rendered more probable from the different Subſtances of which the Cryſtalline is compoſed: It is indeed true, and has been obſerved by Anatomiſts, that tho' this Humour be all very ſolid, in reſpect of the other Humours of the Eye; yet it is not all throughout of the ſame Conſiſtence, being externally like a thick Gelly, but internally, towards its Centre, of a Conſiſtence equal to that of hard Suet: This external ſoft Part of the Cryſtalline is by ſome reckoned to be about the Third of its whole Bulk;

and, in Fiſhes, this Difference of Conſiſtency is in a particular Manner remarkable, who are therefore ſaid to have a double Cryſtalline, the one very ſmall and ſolid, in the Centre of the other, which is larger, but of a ſofter and leſs ſolid Subſtance. This little Cryſtalline, which is as it were a *Nucleus* or Kernel to the other, in whoſe Centre it is placed, is never found wanting in the Eyes of Fiſhes; and indeed in all Animals, ſo far as has been obſerved, this Humour is always much ſofter externally than towards its Centre. But it does not from this follow, that Nature has thus ſoftened the external Part of this Humour, that its Figure may be the more readily varied for ſeeing diſtinctly at all Diſtances, but for another very wiſe and neceſſary Purpoſe: For it is certain, that the Rays of Light which fall upon the Extremities of the Cryſtalline, by reaſon of their greater Obliquity, muſt be more refracted than thoſe which fall upon its Middle, near its Axis, by which means they will be made to meet at different Diſtances behind the cryſtalline Humour; theſe towards its Extremity, nearer, and theſe near its Axis, at a greater Diſtance; ſo that it is impoſſible for all to be united exactly upon the *Retina* for rendering the Sight diſtinct: And therefore, to prevent this Inconveniency, provident Nature, which is never known to do any Thing in vain, but always for the beſt Purpoſes, has very wiſely, towards the Centre of the Cryſtalline, made its Subſtance more denſe and ſolid, that the Rays of Light, that fall on the Cryſtalline, near its Axis, may, in paſſing this *Nucleus*, have their Refraction increaſed, and by that means may be made to converge, and meet at the ſame Point with theſe that paſs the Cryſtalline towards its Edge or Extremity.

This is the Reaſon why the Cryſtalline of all Animals is more ſolid in its Centre than externally, and why in Fiſhes this Difference is ſo remarkable; for in them this Humour being ſpherical, as has been obſerved above, the Rays that fall thereon, at ſome Diſtance from its Axis, by reaſon of their great Obliquity, would be made to meet at a greater Diſtance from the Point of Union of the other Rays that paſs near its Centre, than in Land-Animals who have this Humour lenticular; and therefore, to prevent this Inconveniency, which would have rendered the Sight prodigiouſly indiſtinct, Nature has provided them with that ſmall ſolid Cryſtalline, in the Centre of the other, whoſe Denſity far exceeds that of the *Nucleus* of Land-Animals.

All this might be demonſtrated mathematically; but if a Glaſs *Lens* be covered with opaque Paper, in which there are two Holes, one at the Axis of the Glaſs, and another towards its Edge, and if this Glaſs be placed in a Hole of the Window-ſhut of a dark Room, ſo as to refract a Beam of the Sun's Light upon a Sheet of white Paper, placed at a due focal Diſtance behind the *Lens*, it will be found, that the Beam that paſſeth the Hole towards the Edge of the *Lens*, will cut the *Axis* before the *Focus* of the Glaſs, and fall on the oppoſite Side of the Paper. From all which, it is evident, that the different Conſiſtency obſervable in the cryſtalline Humours, does not prove that they are rendered flatter by the Contraction of the ciliary Proceſs, as ſome Authors would perſuade us, but to diminiſh the Refraction where the Rays fall moſt obliquely, and thereby to diſpoſe them to meet in the ſame Point with thoſe which paſs thro' its Middle, which was abſolutely neceſſary for diſtinct Viſion, unleſs the Pupil had been much leſs than it now is; in which Caſe, our Sight had not been near ſo clear as it is at preſent.

§ 17. If it ſhould be ſaid, that the Cryſtalline changes its Conformation, and becomes more or leſs convex, by the Action of certain muſcular Fibres that enter its Compoſition, it is incumbent on thoſe who entertain this Opinion, to ſhew us theſe Fibres. The Cryſtalline, when dried, does manifeſtly enough appear to be made up of many thin concentrical *Laminæ* or Scales lying one upon another, of which Mr. LEEUWENHOEK reckons there may be 2000 in one Cryſtalline from the outermoſt to the Centre, and every one of theſe Scales, he ſaith, he hath diſcovered to be made up of one ſingle Fibre, or fineſt Thread, wound in a moſt ſtupenduous Manner this way and that way, ſo as to run ſeveral Courſes, and meet in as many Centres, and yet not to interfere or croſs one another in any one Place. In Oxen, Sheep, Hogs, Dogs and Cats, the Thread ſpreads in three ſeveral Courſes, and makes as many Centres; in Whales five, but in Hares and Rabbets only two; in the whole Surface of an Ox's Cryſtalline, he reckons there are more than 12000 Fibres juxta-poſited. But, for the better underſtanding the Manner of this admirable Piece of Mechaniſm, I muſt refer to the Cuts and Deſcriptions in his Works, and in the *Philoſophical Tranſactions*, *num.* 165. and 293. from which it will appear, that this Diſpoſition is but ill qualified for changing the Figure of the Cryſtalline, and for adapting it to the Diſtance of Objects. But ſuppoſing it were otherwiſe, and that it could be made appear that the Diſpoſition is well fitted for that Effect, I am afraid it would not be ſo eaſy to prove thoſe Fibres to be muſcular, and capable of Contraction.

§ 18. There is yet another Argument againſt this Hypotheſis of the Cryſtalline's changing its Figure, by means of muſcular Fibres that enter its Compoſition, which muſt not be omitted; and that is, that it has no viſible Attachment or Communication with any Part of the Body, but is kept in its Place by means of a membranous *Capſule* with which it has not the leaſt Connexion; whence it is, that when this *Capſule* is opened, the Cryſtalline eſcapes of itſelf without the leaſt Violence, as has been obſerved by MAITRE-JEAN, in his *Maladies de l'Oeil, Chap.* xi. and by Dr. PETIT, in the *Memoires de l'Academie Royale, anno* 1730; who therefore make no Scruple to affirm, that of all the Parts of our Body, the Cryſtalline is the only one that has no Continuity with the Parts adjacent, by any Fibre, Blood-veſſel or Nerve: And this Opinion is very much ſtrengthened by a Paſſage I find in STENO's *Canis Carchariæ diſſectum Caput. Cryſtallini humoris propria tunica contenti* (ſays he, ſpeaking of this Animal) *ſubſtantia triplex erat, intima, centrum, centroque vicina loca occupans, dura, et ex lamellis compoſita erat, quæ integræ, cryſtalli inſtar, diaphanæ apparebant, ſectæ verò, albæ ſimul et opacæ evadebant; extima cryſtallini ſubſtantia, tunicæ proxima, aquæ inſtar, diffluebat; reliqua, ut centrum inter et tunicam, medium locum invenerat, ſic etiam conſiſtentiæ mediæ erat, viſciditate ſuâ*

ſuâ gluten æmulans. Solidus globus viſco ſuo circumdatus, liberè in aqua volvebatur. From theſe Words, it is plain, that the Author, who was one of the moſt accurate Anatomiſts of his Time, diſcovered no Attachment of the Cryſtalline to its *Membrane* or *Capſule*, which, had there been any, could not eaſily have eſcaped his Obſervation, where ſo much Water ſurrounded the ſolid Cryſtalline: And this will be ſtill more evident, if we conſider the following Paſſage; from which it appears that he had frequent Opportunities of repeating the like Obſervations. See his *Diſſectio Piſcis ex Canum genere*; where, ſpeaking of the Cryſtlline in one of thoſe canine Fiſhes, he ſays, *Cryſtallini humoris ſubſtantia triplex erat; media dura, et ex lamellis compoſita; huic undique adhærens alia multum glutinoſa; tertia tunicæ proxima, omnino aquea, ſed et hoc piſcibus aliis plurimis datum eſt.*

The famous MORGAGNI has alſo obſerved, that there is Water in the *Capſule* of the Cryſtalline, not only in Men, but in ſeveral other Creatures, *Adverſar.* vi. *p.* 90.); and yet he takes no Notice of any Attachment. But of all the Authors that have written on this Subject, Dr. PETIT ſeems to have carried his Obſervations the fartheſt; for he found this Water not only in the human Eyes, but in the Eyes of Dogs, Cats, Wolves, Hares, Rabbets, Sheep, Lambs, Calves, Oxen, Horſes, Turkies, Ducks, *&c.* but could never diſcover the leaſt Attachment, tho' he ſeems to have been at a good deal of Pains in ſearching after it. See *les Memoires de l' Academie Royale ann.* 1730.

Had the Cryſtalline any Continuity with its *Capſule*, it is probable, that RUYSCH's ſubtile Injections would have reached it; but we find he could never go further than its Membrane, and that only by puſhing forward the Blood in its Veſſels by the ceraceous Matter, from which they became conſpicuous, tho' the ceraceous Matter itſelf could never be made to enter them, (RUYSCH. *Theſaur.* 2. *locul. arc.* 4.) Seeing then that the Cryſtalline has no viſible Attachment or Communication with any Part of the Body, it can never receive into its Fibres any Blood or Spirits; and conſequently it cannot be adapted to the Diſtance of Objects by the Contraction of thoſe Fibres.

If any body ſhould aſk me, How it is poſſible for the Cryſtalline to be nouriſhed, without having ſome Communication with the neighbouring Parts, from which it may derive Blood and Spirits? To this I anſwer, That I ſee no Abſurdity in giving it a Kind of vegetative Life, and in ſuppoſing that it draws Nouriſhment from the Water in which it fluctuates, as MAITRE-JEAN and PETIT have ſuppoſed; and this may be the Reaſon, whence it is that when this Water is wanting, as ſometimes happens in morbid Caſes, the Cryſtalline becomes dry and opaque, much like what it is when taken out of the Eye and dried, as BRISSEAU, MORGAGNI and PETIT have obſerved.

§ 19. The laſt Opinion, concerning the Change made in our Eyes, is what we embrace, and conſiſts in the Motion of the Cryſtalline, whereby the Diſtance betwixt it and the *Retina* is increaſed or diminiſhed according to the different Diſtances of Objects; ſo that at whatever Diſtance Objects are placed, the *Retina* is always at a due focal Diſtance behind the Cryſtalline.

§ 20. Now, the *Ligamentum Ciliare* is an Organ whoſe Structure and Diſpoſition excellently qualify it for changing the Situation of the Cryſtalline, and removing it to a greater Diſtance from the *Retina*, when Objects are too near us; for when it contracts, it will not only draw the Cryſtalline forwards, but it will alſo compreſs the vitreous Humour lying behind it; by which Compreſſion it muſt preſs upon the Cryſtalline, and puſh it forwards farther from the *Retina*. For underſtanding which, let C (PLATE V. *Fig.* 38.) be the Cryſtalline, and let the curve Lines *ao*, *ao* repreſent the

Ligamentum Ciliare; it is eaſy to ſee, that when this Ligament contracts, it muſt draw the Cryſtalline forwards in the Direction of the right Lines *aod*, *aod;* by which means this Humour will be brought nearer the Fore-part of the Eye *oo*. But this is not all; for the Fibres, compoſing this *Ligament* or *muſcular Proceſs*, do not run in a ſtreight Line, from their Origin in the *Choroides*, to their Inſertion in the Edge of the Cryſtalline, but by their Inflexion form a Hollow, behind which lies the vitreous Humour, as repreſented in the Figure; and therefore when they contract, they muſt come nearer to the ſtreight Lines *ao*, *ao*, by which means this Concavity will become leſs, and the vitreous Humour will be compreſſed; which therefore muſt, by preſſing on the Back of the Cryſtalline, puſh it forwards farther from the *Retina*, when we look at near Objects, its Axis all the while remaining the ſame; and the Cryſtalline being moved forwards, muſt at the ſame time preſs the aqueous Humour againſt the *Cornea*; by which Means this Membrane, which is flexible and yielding, will be rendered more convex for enabling us ſtill the better to ſee near Objects diſtinctly.

§ 21. It has been objected to our ſeeing diſtinctly at different Diſtances by means of the Motion of the Cryſtalline, that, upon

Computation, this Motion is found inſufficient to procure diſtinct Viſion at the Diſtances to which the Eye reaches: But as all ſuch Computations are founded upon the Meaſures of the ſeveral Parts of the Eye, their Diſtances from each other, and the refractive Power of the Humours, none of which it is poſſible to aſcertain with that Exactneſs that may be depended on; this Objection is but of little Weight: And beſides, ſuppoſing that the Diſtance betwixt the Cryſtalline and *Retina* could not be ſufficiently increaſed by the Motion of the Cryſtalline for enabling us to ſee diſtinctly at the leaſt Diſtance the Eye can reach to, yet what is wanting in this will be ſupplied by the greater Convexity of the *Cornea*; for when the Cryſtalline is brought forward, its Diſtance from the *Retina* is not only increaſed, but, as has been already noticed, the *Cornea* itſelf is alſo rendered more Convex; which has not been attended to by the Authors of this Objection.

§ 22. PLEMPIUS aſcribes the Diſcovery of the Uſe of this *Ligament*, in changing the Conformation of our Eyes, to the celebrated Philoſopher and Mathematician JOHANNES KEPLERUS, of which Anatomiſts need not be aſhamed, it being only from mathematical Principles that the Neceſſity of any ſuch Change was ever diſcovered. But in explaining

ing this Matter, not only KEPLER, but PLEMPIUS himſelf ſeems to have fallen into a Miſtake; for they ſuppoſe that, by the Contraction of this Proceſs, the Sides of the Eye are drawn inwards towards the Cryſtalline, by which means the Eye is elongated, and the *Retina* is puſhed back to a greater Diſtance behind the Cryſtalline when Objects are near; which is repugnant to the above-noticed Situation of this Proceſs, as well as to the Hardneſs and Inflexibility of the *Sclerotis* of ſeveral Animals. See PLEMPIUS *Ophthalmogr. lib.* iii. *cap.* 9.

§ 23. *M. de la* HIRE denies this Motion of the Cryſtalline, as well as all other Changes made in the Conformation of the Eye; all whoſe Arguments have already been examined at ſome length, excepting thoſe taken from the Structure of the Parts; which now we muſt conſider, in ſo far as they have any Relation to this above deſcribed Motion of the Cryſtalline.

This Author maintains, that it is impoſſible the Cryſtalline can change its Situation, becauſe the *ciliary Ligament* is not muſcular, and conſequently has no Power of Contraction; and of this Opinion are likewiſe a great many Anatomiſts, and in particular HOVIUS; but it appears that all of them have been led into this Miſtake, by an unjuſt Notion they have entertained about the Colour of Muſcles. Every body knows that our Muſcles are generally of a red Colour ; but it does not from thence follow, that what is not red is not muſculous: The muſcular Fibres of the Guts and Stomach have ſcarce any thing of Redneſs in their Colour ; and it is alſo certain that the Pupil does contract and dilate itſelf according as Objects are more or leſs luminous, and yet none of the Fibres which perform that Action are in the leaſt red ; whence it follows, that the Fibres of the *Ligamentum Ciliare* are not to be deprived of a Power of Contraction, becauſe of a Colour different from what generally obtains in other Muſcles; nor are we to be ſurprized that ſo many accurate Anatomiſts, after a careful Examination of this Proceſs, have not ſcrupled to affirm it to be truly muſcular.

The End of the Firſt VOLUME.

ERRATA.

Pag. 18. line 28. *After* longer, *add*, as GALEN in his 10th Book, *De uſu Partium*, has alſo obſerved.
p. 38. l. 21. *For* Figure, *read* Fiſſure.
p. 44. l. 6. *For* VAXHEYEN, *read* VERHEYEN.
p. 55. l. 22. *For* of, *read* or.
p. 65. l. 5. *For* any, *read* only.
p. 69. l. 1. *For* Eye, *read* Eyes.
p. 83. *At the Paragraph, prefix* § 4.
p. 84. *At ſecond ditto, prefix* § 5.
p. 88. l. 16. *For* it is, *read* is it.
p. 134. l. 2. *For* 1, $\frac{17}{19}$, *read* 1$\frac{7}{19}$
l. 3. *For* 9,$\frac{9}{19}$, *read* 9$\frac{9}{19}$
p. 136. l. 6. *For* nor, *read* not.
p. 195. l. 26. *For* a Board, *read* abroad.
p. 215. l. 9. For *Humor*, read *Humore.*
p. 247. l. 12. *For* of, *read* or.
p. 248. *At the ſecond Paragraph, prefix* § 3.
p. 284. l. 11. *For* $\frac{27333{\cdot}8}{10000}$, *read* $\frac{27330{\cdot}8}{10000}$
l. 13. *dele* the.
p. 327. l. 23. *For* 78$\frac{1}{2}$, *read* 77$\frac{1}{2}$
p. 350. l. 6. *For* fell, *read* feel.
p. 353. l. 21. *For* aboard, *read* abroad.
p. 377. l. 16. *For* Glaſs, *read* the Glaſs.
l. 17. *For* the Glaſs, *read* Glaſs.
p. 389. l. 2. *For* as, *read* at.
p. 406. l. 7. *After* then, *add* it.
p. 425. *before line* 3. *add* § 9.
p. 428. *before line* 4. *add* § 12.

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Fig. 1.

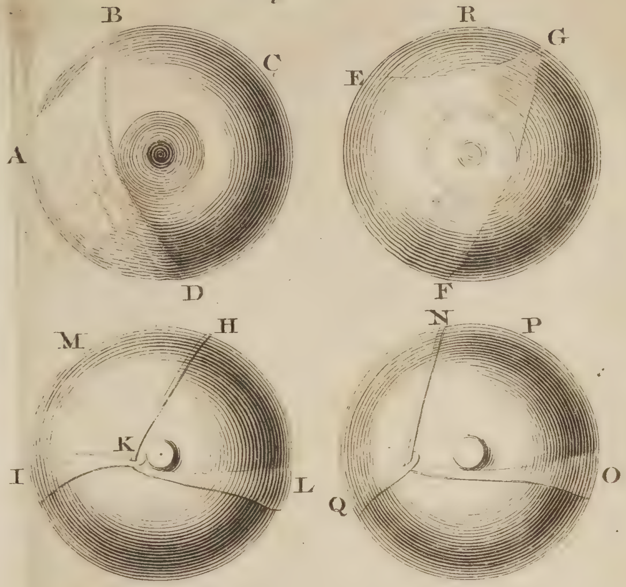
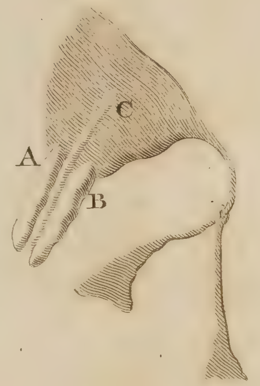


Fig. 2.



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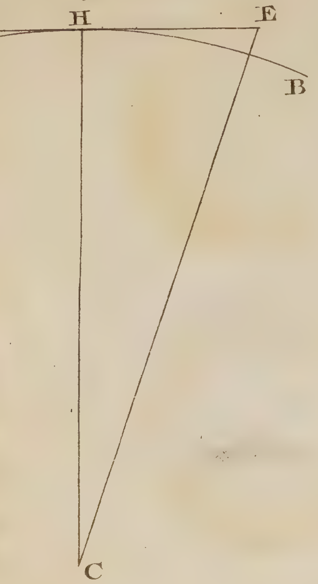

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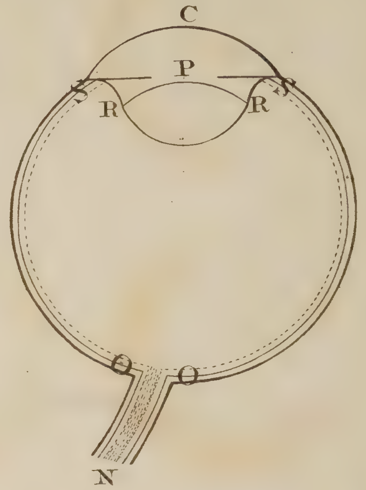

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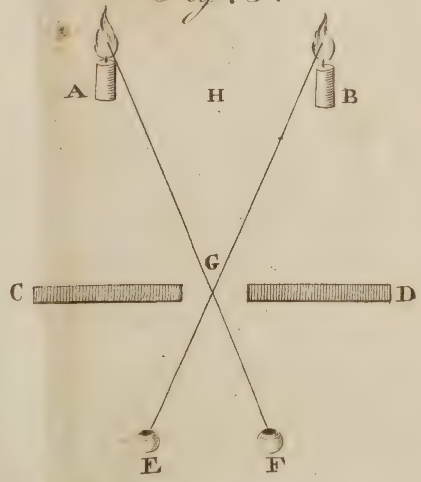

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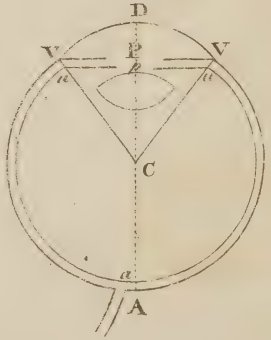

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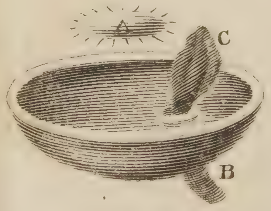

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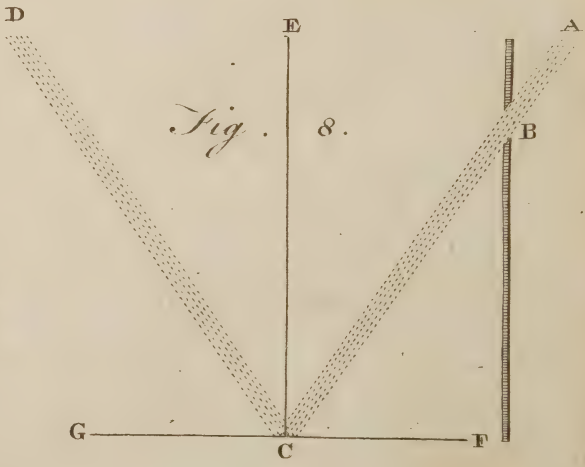

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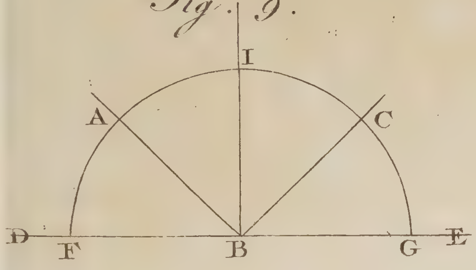
Fig. 9.



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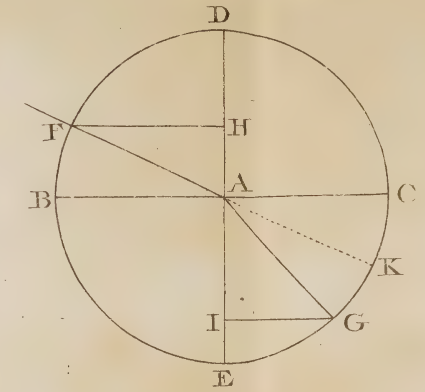

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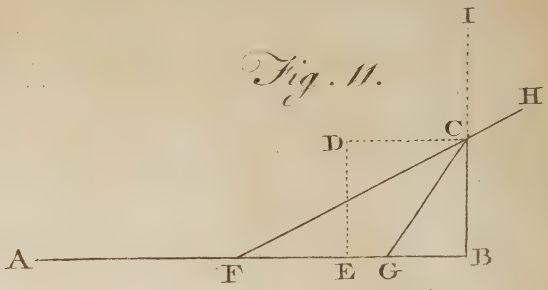

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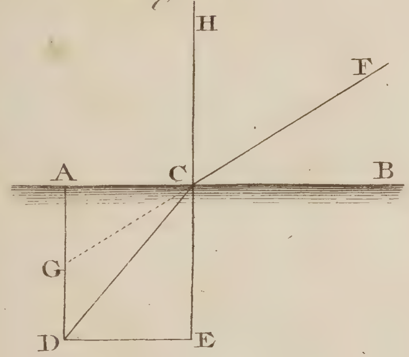

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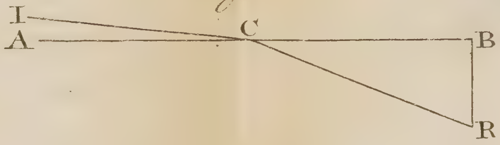

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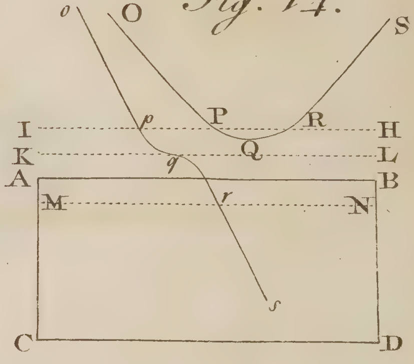

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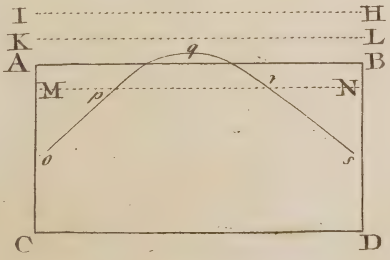

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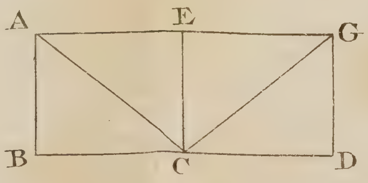

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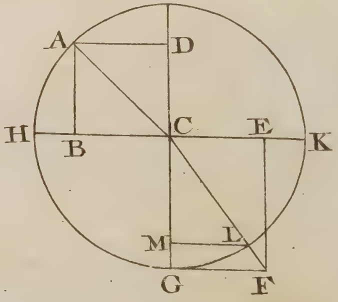

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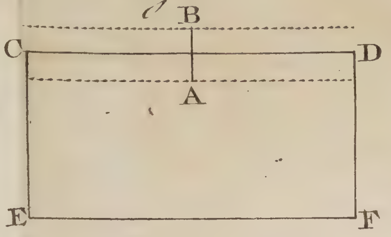
Fig. 18.



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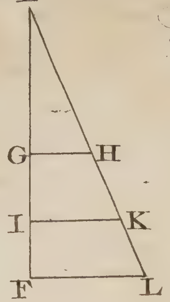

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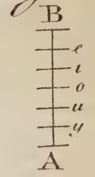

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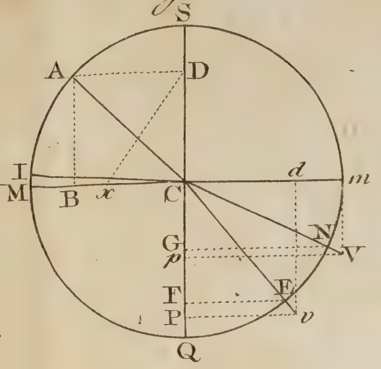

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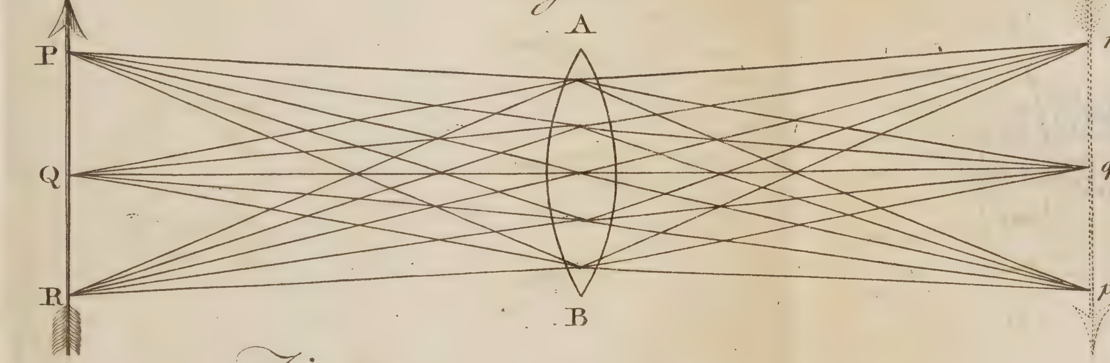

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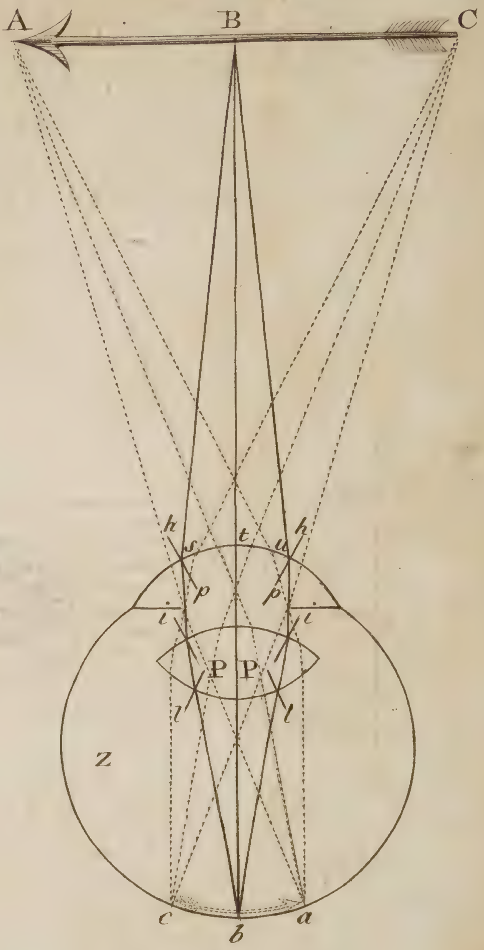

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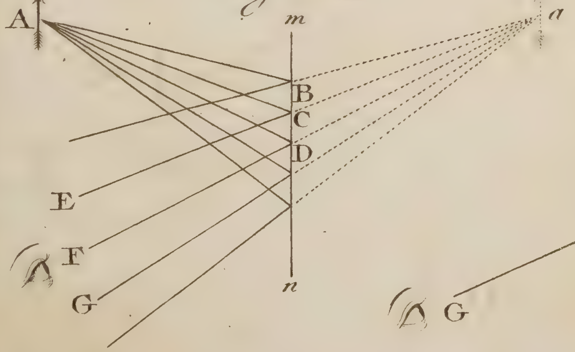

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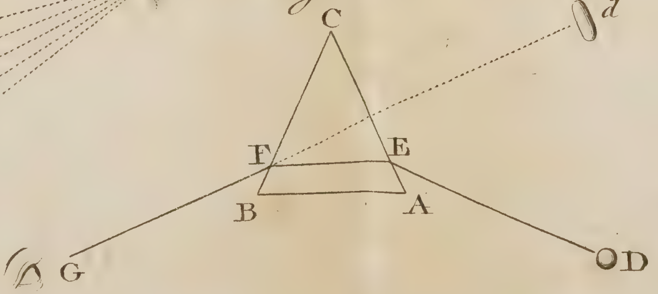

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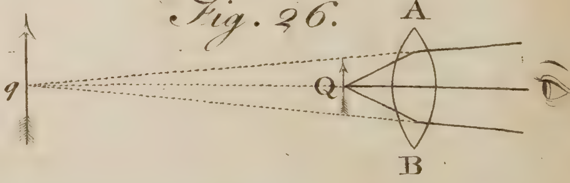

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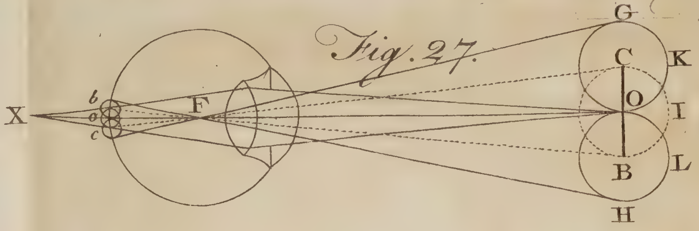
Fig. 27.



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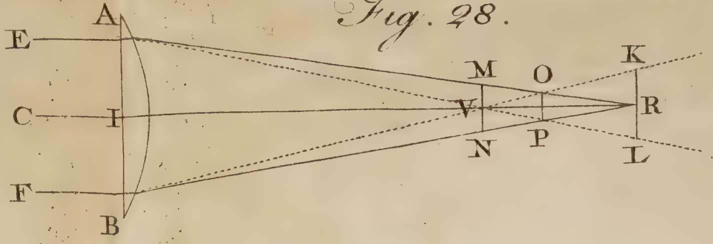

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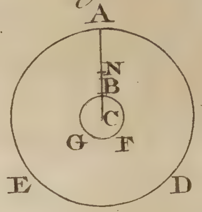

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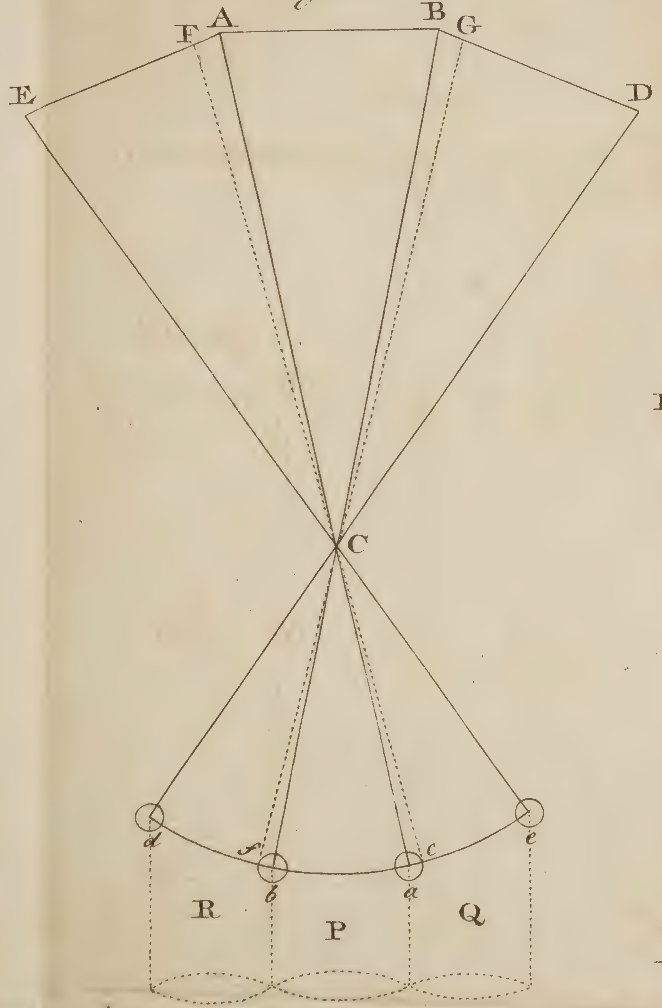

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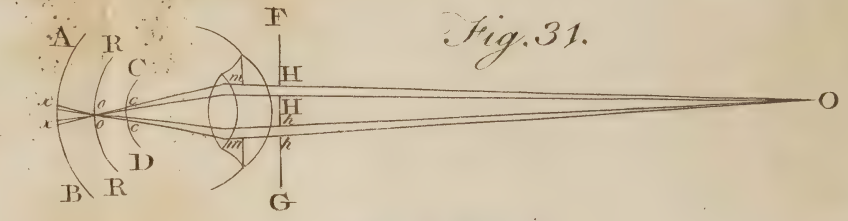

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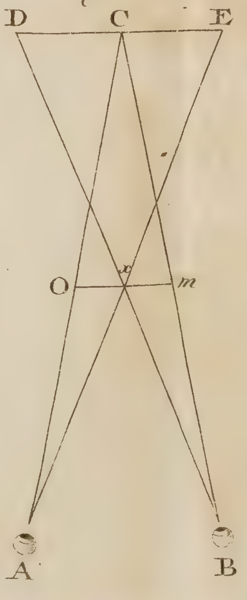

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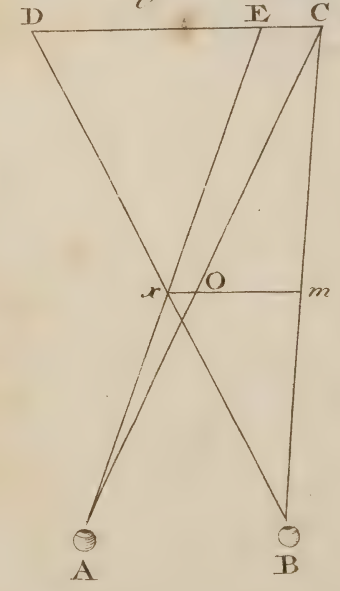

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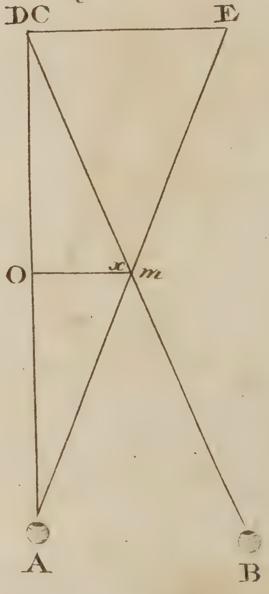

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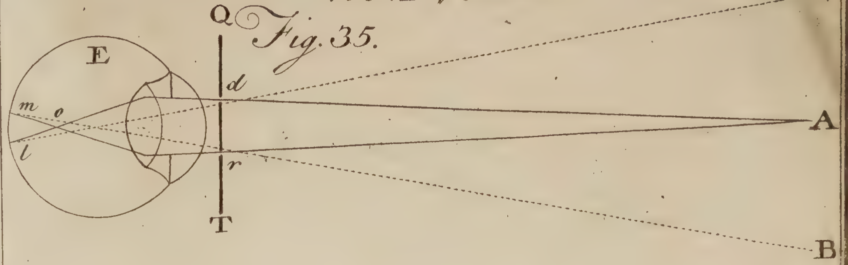
Fig. 35.



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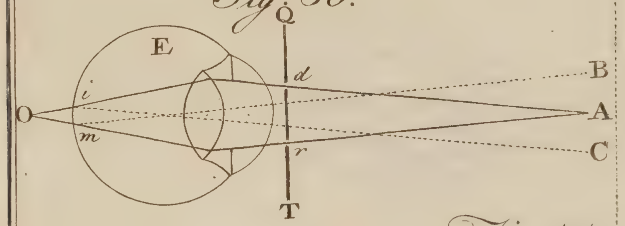

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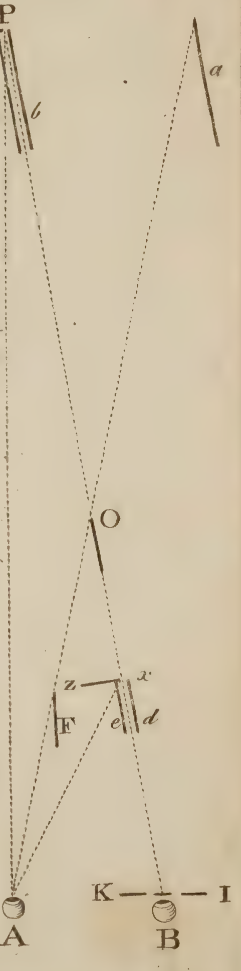

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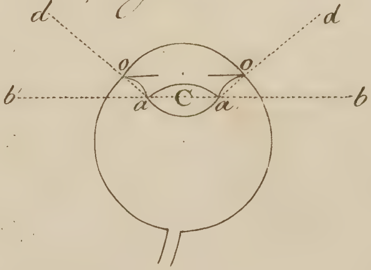

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